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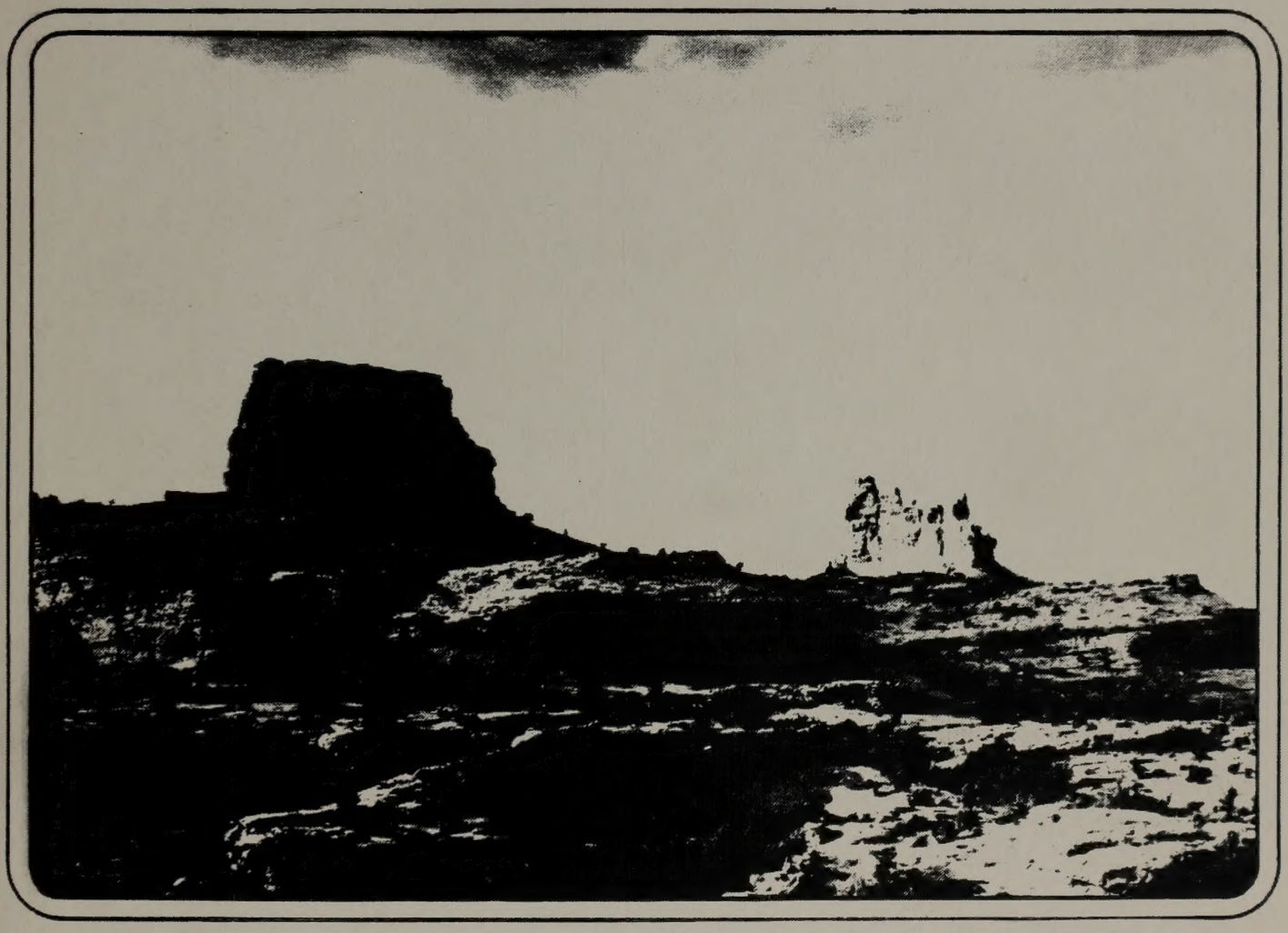

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FEDERAL PROTOTYPE OIL SHALE TRACTS Ua AND Ub

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prepared by

White River Shale Oil Corporation
115 South Main Street, Suite 500
Salt Lake City, Utah 84111

May, 1984

TABLE OF CONTENTS

Section			Page
1.0	INTRODUCTION		1-1
	1.1	Purpose	1-1
	1.2	Background	1-2
	1.3	Summary of Results	1-6
2.0	AIR RESOURCES		2-1
	2.1	Introduction	2-1
		2.1.1 Program Objectives	2-1
		2.1.2 Program Evolution	2-2
	2.2	Summary	2-5
	2.3	Program Description	2-7
		2.3.1 Air Quality Monitoring Program	2-7
		2.3.2 Meteorological Monitoring Program	2-11
		2.3.3 Sound Level Measurement Program	2-14
		2.3.4 Quality Assurance/Quality Control Program	2-14
	2.4	Program Results and Analysis	2-17
		2.4.1 Air Quality	2-17
		2.4.2 Atmospheric Processes	2-39
		2.4.3 Sound Levels	2-78
		2.4.4 Special Studies	2-81
	2.5	References	2-94
3.0	VEGETATION RESOURCES		3-1
	3.1	Introduction	3-1
	3.2	Summary	3-2
		3.2.1 Production of Annual Plant Biomass	3-2
		3.2.2 Sagebrush Leader Growth	3-2
		3.2.3 Plant Chemical Composition	3-3
		3.2.4 Litterfall Measurements	3-3
		3.2.5 Assessment of Animal Utilization of Plants	3-4
		3.2.6 Lichen Monitoring	3-4
		3.2.7 Plant Condition and Stress	3-5
		3.2.8 Soil Microbiology and Soil Chemistry	3-5
		3.2.9 Revegetation Success on Disturbed Sites	3-7

TABLE OF CONTENTS (continued)

Section			Page
3.0	VEGETATION RESOURCES (continued)		
	3.3	Program Description	3-9
		3.3.1 Objectives	3-9
		3.3.2 Site Locations	3-9
		3.3.3 Methods	3-10
		3.3.4 QA/QC Program	3-10
	3.4	Program Results and Analysis	3-13
		3.4.1 Production of Annual Plant Biomass	3-13
		3.4.2 Sagebrush Leader Growth	3-17
		3.4.3 Plant Chemical Composition	3-25
		3.4.4 Litterfall Measurements	3-25
		3.4.5 Assessment of Animal Use of Plants	3-40
		3.4.6 Use of Lichens as Biological Monitors of Air Pollution	3-43
		3.4.7 Plant Condition and Stress	3-55
		3.4.8 Soil Microbiology and Soil Chemistry	3-59
		3.4.9 Revegetation Success on Disturbed Sites	3-79
	3.5	References	3-84
4.0	AQUATIC BIOLOGY		4-1
	4.1	Introduction	4-1
	4.2	Program Summary	4-3
	4.3	Program Description	4-6
		4.3.1 1983 Monitoring Program	4-6
		4.3.2 Quality Control Program	4-9
	4.4	Program Results and Analysis	4-18
		4.4.1 The Physical Environment	4-18
		4.4.2 The Chemical Environment	4-30
		4.4.3 The Organic Environment	4-41
		4.4.4 Primary Producers	4-42
		4.4.5 Consumers	4-49
		4.4.6 Decomposers	4-61
		4.4.7 Comparisons of Biological Parameters on Control and Treatment Sites	4-63
		4.4.8 Variability of Biological Parameters Within Transects	4-68
		4.4.9 Use of Controlled Substrates for Benthic Macro-invertebrate Monitoring	4-72
	4.5	References	4-81

TABLE OF CONTENTS (continued)

Section		Page
5.0	TERRESTRIAL FAUNA	5-1
5.1	Introduction	5-1
5.2	Summary	5-4
5.2.1	Studies of the Rodent-trapping Grids	5-4
5.2.2	Soil Invertebrates	5-4
5.2.3	Foliage Invertebrates	5-5
5.2.4	Reptiles	5-6
5.2.5	Birds	5-7
5.2.6	Mammals	5-8
5.3	Program Description	5-9
5.3.1	Objectives	5-9
5.3.2	Sampling Locations	5-9
5.3.3	Methods	5-9
5.4	Program Results and Analysis	5-16
5.4.1	Studies of the Rodent-trapping Grids	5-16
5.4.2	Soil Invertebrates	5-36
5.4.3	Foliage Invertebrates	5-38
5.4.4	Reptiles	5-55
5.4.5	Birds	5-63
5.4.6	Mammals	5-90
5.5	References	5-105
6.0	WATER RESOURCES	6-1
6.1	Introduction	6-1
6.2	Summary	6-2
6.2.1	Hydrometeorology	6-2
6.2.2	Surface Water	6-2
6.2.3	Ground Water	6-4
6.3	Program Description	6-6
6.3.1	Hydrometeorology	6-6
6.3.2	Surface Water	6-7
6.3.3	Ground Water	6-10
6.3.4	Quality Assurance/Quality Control Program	6-13
6.4	Results and Analysis	6-19
6.4.1	Hydrometeorology	6-19
6.4.2	Surface Water	6-34
6.4.3	Ground Water	6-74

TABLE OF CONTENTS (continued)

Section		Page
6.0 WATER RESOURCES (continued)		
6.5	References	6-99
7.0	SPECIAL STUDIES	7-1
7.1	Reclamation Research	7-2
7.1.1	Introduction	7-2
7.1.2	Program Summary	7-3
7.1.3	Program Description	7-6
7.1.4	Program Results and Analysis	7-8
7.1.5	References	7-55
	Appendix	7-57
7.2	White River Ecosystem Metals Study	7-58
7.2.1	Introduction	7-58
7.2.2	Program Summary and Recommendations	7-61
7.2.3	Program Description	7-64
7.2.4	Program Results and Analysis	7-68
7.3	Vegetal and Soil Characteristics Influencing Rodent Populations	7-115
7.3.1	Introduction	7-115
7.3.2	Program Summary	7-116
7.3.3	Program Description	7-116
7.3.4	Program Results and Analysis	7-121
7.3.5	References	7-141
Appendix A		7-143
A.1	Vegetation	7-143
A.1.1	Sagebrush-Greasewood Vegetation Type	7-143
A.1.2	Juniper Vegetation Type	7-148
A.1.3	Shadscale Vegetation Type	7-152
A.1.4	Riparian Vegetation Type	7-156
A.1.5	Literature Cited	7-162
Appendix B		7-175
B.1	Soil Taxonomy	7-175
B.1.1	Soil Classification	7-175
B.1.2	Map Unit Descriptions	7-177
B.2	Soil Taxa	7-194
B.2.1	(11Kbc) Type Description	7-194
B.2.2	(11Kbc) Type Description	7-195
B.2.3	(12Kd) Type Description	7-195

TABLE OF CONTENTS (continued)

Section		Page
7.0	SPECIAL STUDIES (continued)	
	B.2.4 (13Xde and 14Xc) Type Description	7-196
	B.2.5 (21bc) Type Description	7-196
	B.2.6 (22b) Type Description	7-197
	B.2.7 (22Kbc) Type Description	7-197
	B.2.8 (31a) Type Description	7-198
	B.2.9 (32a) Type Description	7-199
	B.2.10 (33ab) Type Description	7-200
	B.2.11 (41b) Type Description	7-200
	B.2.12 (51b) Type Description	7-201
	B.2.13 (61a) Type Description	7-202
	B.2.14 (62a) Type Description	7-203
	B.2.15 (63a) Type Description	7-203
	B.2.16 (71a) Type Description	7-204
	B.2.17 (72a) Type Description	7-205
	B.3 Literature Cited	7-205
8.0	ECOSYSTEM ANALYSIS	8-1
	8.1 Introduction	8-1
	8.2 Summary	8-7
	8.2.1 Development of a Data Library and Cataloging System	8-7
	8.2.2 Program Review	8-10
	8.2.3 Evaluation of Precipitation and Evaporation Data	8-12
	8.2.4 Evaluation of Vegetation Parameters for Monitoring	8-14
	8.3 Program Description	8-15
	8.3.1 Introduction	8-15
	8.3.2 Objectives	8-15
	8.4 Program Results and Analysis	8-17
	8.4.1 Evaluation of Precipitation and Evaporation Data	8-17
	8.4.2 Evaluation of Vegetation Parameters for Monitoring	8-39
	8.4.3 Recommendations	8-85
	Literature Cited	8-89

LIST OF TABLES

Table		Page
2.3-1	Air quality monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1983.	2-9
2.3-2	Percentage of time air quality parameters were monitored during January 1 - December 31, 1983.	2-10
2.3-3	Meteorological monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1983.	2-12
2.3-4	Percentage of data recovered for meteorological parameters during January 1 - December 31, 1983.	2-13
2.4-1	Comparison of seasonal minimum, mean and peak 1-hour ozone concentrations between 1983 and baseline (1975-1981).	2-20
2.4-2	Comparison of seasonal mean and peak 1- and 8-hour CO concentrations between 1983 and baseline (1975-1981).	2-26
2.4-3	Comparison of seasonal mean and peak 1-hour NO_2 concentrations between 1983 and baseline (1975-1981).	2-29
2.4-4	Comparison of seasonal mean and peak 3- and 24-hour SO_2 concentrations between 1983 and baseline (1975-1981).	2-31
2.4-5	Precision and accuracy of the TSP samplers at Site A4 during 1983.	2-34
2.4-6	Comparison of seasonal geometric means, standard geometric deviations, maximum and minimum 24-hour particulate concentrations between 1983 and baseline (1975-1981).	2-37
2.4-7	Annual average and annual geometric mean pollutant concentrations for the entire monitoring period.	2-38
2.4-8	Maximum observed concentrations corresponding to relevant short-term averaging times for the entire monitoring period.	2-41
2.4-9	Averaging criteria, U.S. EPA, 1977.	2-41
2.4.10	Comparison between national and Utah air quality standards for air pollutants with maximum levels observed for the Ua/Ub tracts in 1983.	2-42
2.4-11	Monthly average wind speeds and prevailing directions for 1983.	2-46

LIST OF TABLES (continued)

Table		Page
2.4-12	Monthly minimum, mean and maximum temperatures for 1983.	2-58
2.4-13	Monthly minimum, mean and maximum relative humidity for 1983 versus baseline (1975-1981) at A6.	2-62
2.4-14	Monthly minimum, mean and maximum barometric pressure for Site A6.	2-65
2.4-15	Relative frequency distribution of diffusion classes using σ_θ at A6 during 1983 and the baseline period.	2-68
2.4-16	Classification of atmospheric diffusivity using σ_θ.	2-70
2.4-17	Relative frequency distribution of stability classes using ΔT at A6 during 1983 and the baseline period.	2-73
2.4-18	Classification of atmospheric stability using ΔT.	2-74
2.4-19	Relative frequency of low wind speed combined with very stable atmospheric conditions in 1983 at Site A6.	2-77
2.4-20	Annual averages of the meteorological parameter measured during the entire monitoring period at A6.	2-79
2.4-21	Summary of peak and average sound level data for 1981-1983.	2-80
2.4-22	Quality control data - spiked sample data.	2-84
2.4-23	Quality control data - duplicate sample data.	2-85
2.4-24	Results of rainfall chemistry analysis.	2-86
2.4-25	Storm air mass data.	2-87
2.4-26	September 23, 1983 meteorological data.	2-89
2.4-27	Mean ambient No_x and SO_2 during days with precipitation.	2-90
3.4-1	Biomass production of annual understory vegetation of four primary vegetation types during 1983 and compared with previous years.	3-16
3.4-2	A comparison of sagebrush stem growth over a nine year period, 1975-1983.	3-21
3.4-3	Two-Way Analysis of Variance test of sagebrush stem growth for 1975-1983.	3-22
3.4-4	Average leader growth measurements of fourwing saltbush, greasewood, rabbitbrush, and sagebrush from Site 7.	3-24

LIST OF TABLES (continued)

Table		Page
3.4-5	Comparions of 1981, 1982 and 1983 elemental analysis of sagebrush leader collected from seven sagebrush leader growth sites.	3-26
3.4-6	General locations of species receiving litter fall catchments.	3-28
3.4-7	Litterfall from juniper for the period June 6, 1983 - October 10, 1983.	3-31
3.4-8	Litterfall sagebrush for the period June 6, 1983 - October 10, 1983.	3-32
3.4-9	Litterfall from greasewood for the period June 6, 1983 - October 10, 1983.	3-33
3.4-10	Litterfall from hopsage for the period June 6, 1983 - October 10, 1983.	3-34
3.4-11	Litterfall from Green's rabbitbrush for the period June 6, 1983 - October 10, 1983.	3-35
3.4-12	Litterfall from shadscale for the period June 6, 1983 - October 10, 1983.	3-36
3.4-13	Litterfall from fourwing saltbush for the period June 6, 1983 - October 10, 1983.	3-37
3.4-14	Litterfall on the seven species studies for a 16-month period.	3-38
3.4-15	Litterfall composition, total litterfall, size indexes, the total litter per size index for each of the seven species studied for the period June, 1982 - October, 1983.	3-39
3.4-16	Results of Cole Browse Survey taken in April 1983.	3-42
3.4-17	Leader lengths of Caged and Non-Caged big Sagebrush Shrubs.	3-42
3.4-18	Frequency of all lichen species encountered along the NW transects, 1983.	3-47
3.4-19	Frequency of all lichen species encountered along the NE transects, 1983.	3-48
3.4-20	Frequency for all lichen species encountered along the SE transects, 1983.	3-49
3.4-21	Comparison of lichen monitoring stands based on 1982 and 1983 values estimated for average percentage cover and average number of species/quadrat.	3-50

LIST OF TABLES (continued)

Table		Page
3.4-22	Selection of 8 most abundant species for the lichen monitoring program.	3-52
3.4-23	Comparions of key monitoring parameters between 1982 and 1983.	3-54
3.4-24	Summary of data collected on plant stress using CIR photography, 1982 and 1983.	3-58
3.4-25	Result of soil chemistry analysis, October 1983.	3-61
3.4-26	Results of soil microbiology analysis, October 1983.	3-62
3.4-27	Monthly means for chemical and microbiological characteristics of WRS soils.	3-63
3.4-28	Yearly summary by site of the soil and microbiological data taken during 1983.	3-65
3.4-29	Direct algal counts for the October soil samples for eight sites.	3-73
3.4-30	Correlation coefficients linking chemical and microbiological parameters for tracts Ua and Ub soils.	3-78
3.4-31	Seedling density on reclaimed areas 1 year after seeding.	3-81
3.4-32	Revegetation success of transplanted shrubs at Site 3 along main access road to the plant site.	3-83
4.3-1	Daily quality control results for ammonia analyses for the 1983 aquatic monitoring program.	4-12
4.3-2	First quarter results of EPA audit samples for 1983.	4-14
4.4-1	Mean width, depth and velocity characteristics of White River monitoring transects during 1981-1983.	4-24
4.4-2	Mean substrate composition of White River monitoring transects during 1981-1983.	4-25
4.4-3	Presence of taxa of periphytic algae present on the White River near Tracts Ua and Ub.	4-47
4.4-4	Taxa of aquatic invertebrates documented by the WRSOC aquatic monitoring program in the White River near Tracts Ua and Ub.	4-54

LIST OF TABLES (continued)

Table		Page
4.4-5	Classification of aquatic invertebrates found in the White River during 1981-1983.	4-56
4.4-6	ANOVA for the biomass of macroinvertebrates.	4-65
4.4-7	ANOVA for the numbers of macroinvertebrates.	4-65
4.4-8	ANOVA on chlorophyll *a*.	4-67
4.4-9	Results of randomization tests on c.v. for single and multiple location estimates.	4-70
4.4-10	Coefficients of variation for parameter estimates from WRO3.	4-70
4.4-11	Coefficients of variation for parameter estimates from WRO3.	4-71
4.4-12	Comparison between numbers and coefficient of variation of samples.	4-78
4.4-13	Comparison between biomass and coefficient of variation of samples.	4-78
5.1-1	Monitoring parameters of terrestrial fauna at the Utah Oil Shale Tracts, Ua and Ub.	5-2
5.4-1	Map unit legend.	5-17
5.4-2	Map unit occurrence for rodent-trapping grids.	5-18
5.4-3	Factors limiting the distribution and abundance of burrowing rodents.	5-19
5.4-4	Annual-plant cover, height, and biomass for each of ten rodent-trapping grids.	5-25
5.4-5	Percent bare ground, rock, litter and annual, perennial and total plant cover for ten rodent-trapping grids.	5-27
5.4-6	Importance values of the three most dominant plant species within each rodent-trapping grid.	5-28
5.4-7	Map unit codes and descriptions for the rodent-trapping grid vegetation maps.	5-29
5.4-8	Seed production for eight perennial species and one annual grass that are dominant on one or more of the upland rodent-trapping grids.	5-31

LIST OF TABLES (continued)

Table		Page
5.4-9	Seed production for nine plant species that are dominant on one or more of the upland rodent-trapping grids.	5-33
5.4-10	Germinated, ungerminated, and diseased cheatgrass seeds from soil samples.	5-35
5.4-11	Total individuals of foliage invertebrate in 9 functional groups sampled with beat net in 1982 and 1983.	5-40
5.4-12	Summary of monthly sampling schedule of foliage invertebrates in 1982 and 1983.	5-41
5.4-13	Mean values of water potential and invertebrate abundance, biomass, richness and diversity on 9 host plants from May to October, 1983.	5-45
5.4-14	Mean values of water potential for big sagebrush and invertebrate faunal characteristics for big sagebrush from May to October, 1983.	5-51
5.4-15	Mean biomass of the most important vertebrate functional groups on big sagebrush in four vegetation types from May to October, 1983.	5-56
5.4-16	Consuming biomass of avian foraging guilds in April 1983 on the Utah Shale Oil Tract, Ua and Ub.	5-64
5.4-17	Consuming biomass of avian foraging guilds in June 1983 at the Utah Shale Oil Tracts, Ua and Ub.	5-66
5.4-18	Waterfowl abundance along the White River from Cowboy Canyon to Asphalt Wash.	5-78
5.4-19	Number of active raptor nests in the vicinity of the Utah Oil Shale Tracts, Ua and Ub, in 1982 and 1983.	5-84
5.4-20	Condition of 90 raptor nests located on or within two miles of Utah Oil Shale Tracts Ua and Ub, as of June 1983.	5-86
5.4-21	Summary of raptor nestling productivity for 1983 on and near the Utah Oil Shale Tracts, Ua and Ub.	5-87
5.4-22	Results of bald eagle survey along the White River in winter, 1982 and 1983.	5-89
5.4-23	Densities of desert cottontails in 1983.	5-100

LIST OF TABLES (continued)

Table		Page
5.4-24	Mule deer observations on or near Utah Oil Shale Tracts Ua and Ub, in 1983.	5-103
5.4-25	Abundance of mule deer along flushing transects in 1983.	5-104
6.4-1	Monthly Summary Water Balance - March 5-July 31, 1983.	6-31
6.4-2	Suspended Sediment and Field Water Quality Data for Evacuation Creek Station 09306430.	6-40
6.4-3	Water Quality Data for Evacuation Creek Station 09306430.	6-44
6.4-4	Outliers Detected in the 1983 Water Quality Data Collected at Evacuation Creek Station 09306430.	6-46
6.4-5	Contribution of Runoff From the Upper and Lower Basins of the White River Drainage.	6-54
6.4-6	Suspended Sediment and Field Water Quality Data at White River Station 09306430.	6-56
6.4-7	Suspended Sediment and Field Water Quality Data at White River Station 09306430.	6-57
6.4-8	Water Quality Data for White River Stations 09306395 and 09306700.	6-64
6.4-9	Outliers Detected in the 1983 Water Quality Data Collected at White River Station 09306700.	6-71
6.4-10	Static Ground Water Levels for Bird's Nest Zone Wells.	6-83
6.4-11	Water Quality Data Summary for Wells G-5 and G-11.	6-88
6.4-12	Water Quality Data for Well UF-1.	6-95
6.4-13	Static Ground Water Levels and Water Quality for Alluvial Wells.	6-96
7.1-1	Root weights per 1000 grams of soil taken from Anvil Points on June 6, 1983.	7-11
7.1-2	Root weights per 1000 grams of soil sampled at Section 6, Bonanza, Utah, June 1983.	7-13
7.1-3	Soil samples taken from Anvil Points.	7-14
7.1-4	pH values from different depths in topsoil trench study at Anvil Points.	7-16

LIST OF TABLES (continued)

Table		Page
7.1-5	Electrical conductivity values sampled from different depths in topsoil trench at Anvil Points.	7-17
7.1-6	Plant height and cover estimates.	7-19
7.1-7	Summary of survival of plantings at Anvil Points.	7-22
7.1-8	Summary of growth of plantings at Anvil Points.	7-25
7.1-9	Seed mixes used on topsoil pile soil microbiology study.	7-31
7.1-10	Summary of percentage survival of transplants for the interplanting/Interseeding study.	7-35
7.1-11	Seed mix used for interseeding study.	7-38
7.1-12	Interplanting preliminary results.	7-40
7.1-13	Chemical Analysis of the Circular Grate Leachate Trials.	7-46
7.1-14	The growth of 12 species into circulate grate processed shale after 6 weeks.	7-51
7.2-1	The average concentrations for selected water quality parameters in the White River.	7-60
7.2-2	The comparison of physical, chemical and biological structural parameters in the White River.	7-69
7.2-3	A summary of all metals data collected in the White River by date.	7-71
7.2-4	The temporal and spatial concentration of metals in various trophic categories of the White River.	7-72
7.2-5	The ICP analysis of the elemental components of the precipitates collected from the White River.	7-77
7.2-6	The cadmium concentration of fish organs at selected locations in the White River.	7-79
7.2-7	The concentration of selected water quality parameters for several surface water sources to the study section of the White River.	7-85
7.2-8	The concentration of selected water quality parameters from alluvial wells in major drainages to the White River.	7-87

LIST OF TABLES (continued)

Table		Page
7.2-9	A two-way analysis of variance for metals in White River macroinvertebrates when compared between three river transects and within transect locations.	7-90
7.2-10	The concentrations of Cd, Cr, Cu, Pb, Ni and Zn for various components of the aquatic ecosystem from selected studies.	7-96
7.2-11	The concentration factors from water into each major component of the White River ecosystem.	7-97
7.2-12	The regression equations between the metal concentrations in precipitates and macroinvertebrates in the White River.	7-108
7.2-13	The net production, respiration and gross production estimates from the control and treatment chambers in the White River.	7-111
7.2-14	The soluable concentrations of Pb, Cu and Zn in the experimental production/respiration chambers in the White River.	7-112
7.3-1	Percent of occurrence, plant cover, canopy height, and vegetal structure for vegetation groups.	7-122
7.3-2	Percent occurrence, geographic position, soil depth and soil rockiness of the soil groups.	7-124
A.1.1-1	Plant species occurring on the 10 rodent trapping grids.	7-163
A.1.1-2	Cover, density, frequency, and importance values for the perennial plant found within each rodent trapping grid.	7-166
A.1.1-3	Percent bare ground, rock, litter, annual, and perennial plant cover and total plant cover.	7-174
B.1.1-1	Distinguishing taxonomic criteria to the subgroup level.	7-176
B.1.2-1	Map unit legend for soils in 10 rodent trapping grids.	7-178
8.1-1	Summary of program goals for all aspects of the WRSOC environmental monitoring program.	8-3
8.4-1	Matrix of precipitation data collection since 1974.	8-25
8.4-2	Results of two-way ANOVA testing for differences between precipitation gage locations.	8-28

LIST OF TABLES (continued)

Table		Page
8.4-3	Results of two-way ANOVA testing for differences between precipitation gage locations.	8-30
8.4-4	Monthly precipitation values in inches during 1981 and 1982 water years for stations included in cluster analysis.	8-32
8.4-5	Matrix of evaporation data collection since 1975.	8-34
8.4-6	ANOVA for evaporation data from EVP-2 and EVP-13.	8-35
8.4-7	ANOVA for evaporation data from EVP-2 and EVP-13.	8-36
8.4-8	ANOVA of ASBP by year.	8-59
8.4-9	Mean ASBP for 1978, 1979, 1981 and 1982.	8-59
8.4-10	Two-way ANOVA of transformed ASBP by vegetation type and year.	8-60
8.4-11	Statistical measures for ASBP by vegetation type.	8-61
8.4-12	Summary of results of ANOVA(s) between years for each of four vegetation types.	8-62
8.4-13	Two-way ANOVA of ASBP by plot and year.	8-63
8.4-14	Statistical measures for ASBP by plots.	8-64
8.4-15	Partitioning of total variability.	8-65
8.4-16	Regression analyses of ASBP by vegetation types and October-May precipitation.	8-66
8.4-17	Sample size necessary to establish an estimate of ASBP with a 95% confidence interval.	8-68
8.4-18	Statistical summary for SLG.	8-71
8.4-19	Two-way ANOVA of SLG for plots and years.	8-73
8.4-20	Statistical measures of SLG by year.	8-73
8.4-21	Statistical measures of SLG by plot.	8-74
8.4-22	Regression analysis of SLG and October-March precipitation.	8-77
8.4-23	Regression of seasonal precipitation and net radiation with SLG.	8-78

LIST OF TABLES (continued)

Table		Page
8.4-24	Regression of SLG with seasonal precipitation, net radiation and temperature.	8-79
8.4-25	Regression of SLG with seasonal precipitation and PET.	8-80
8.4-26	Results of modeling.	8-81
8.4-27	Sample size necessary to establish an estimate of SLG with a 95% confidence interval.	8-84
A-1	Seasonal Climatic Data.	8-97
A-2	Production Values for SLG.	8-97

LIST OF FIGURES

Figure		Page
1.2-1	Project Location Map	1-3
2.3-1	Locations of meteorological and air quality measurement stations on Tracts Ua and Ub during 1983.	2-8
2.3-2	Sound level measuring sites.	2-15
2.4-1	Seasonal minimum, mean and maximum ozone values from February 1975 through December 1983.	2-18
2.4-2	Diurnal distribution of hourly ozone concentrations for January and July 1983.	2-21
2.4-3	Ozone pollution roses for Site A4 for 1983 and Site A6 for baseline period.	2-23
2.4-4	Seasonal trend of hourly maximum and mean carbon monoxide concentrations.	2-25
2.4-5	Seasonal trend of hourly NO_2 maximum and mean concentrations.	2-28
2.4-6	Seasonal trend of hourly SO_2 maximum and mean concentrations.	2-30
2.4-7	Seasonal minimum geometric mean and maximum 24-hour TSP trends.	2-35
2.4-8	Trends of annual averages of all pollutants during the monitoring program at the background station.	2-40
2.4-9	Normal sea level pressure in mb and temperature in °F.	2-44
2.4-10	Seasonal mean and peak hourly wind speed (10m) trends for the monitoring period at A6.	2-47
2.4-11	Typical flow pattern on Tracts Ua and Ub during 1975-1979.	2-49
2.4-12	Monthly averaged hourly wind speed (10m) for January and July 1983 versus baseline for Site A6.	2-51
2.4-13	Directional wind roses at the monitoring stations on the tracts for winter 1983.	2-53
2.4-14	Directional wind roses at the monitoring stations on the tracts for spring 1983.	2-54
2.4-15	Directional wind roses at the monitoring stations on the tract for summer 1983.	2-55
2.4-16	Directional wind roses at the monitoring stations on the tracts for fall 1983.	2-56

LIST OF FIGURES (continued)

Figure		Page
2.4-17	Seasonal maximum, mean, and minimum hourly temperatures (10m) at A6 for 1975 through 1983.	2-57
2.4-18	Monthly averaged January and July temperatures (10m) in 1983 versus baseline for Site A6.	2-59
2.4-19	Seasonal maximum, mean, and minimum relative humidity at A6 for 1975 through 1983.	2-60
2.4-20	Monthly averaged January and July hourly relative humidity in 1983 versus baseline for Site A6.	2-63
2.4-21	Site A6 seasonal barometric pressure for 1975 through 1983.	2-64
2.4-22	Monthly averaged January and July hourly net thermal radiation in 1983 versus baseline for A6.	2-67
2.4-23	Diurnal distribution of σ_θ at Site A6 for January and July 1983 versus baseline.	2-71
2.4-24	Diurnal variation at ΔT at Site A6 for January and July 1983 versus baseline.	2-75
3.3-1	Location of Vegetation Resources Study Areas.	3-11
3.4-1	Regression analysis of precipitation with Annual Species Biomass.	3-15
3.4-2	Graph of Sagebrush stem growth and winter precipitation.	3-19
3.4-3	Regression of sagebrush stem growth and winter precipitation.	3-20
3.4-4	Typical placement of a 1/2 m^2 trap under greasewood.	3-29
3.4-5	Placement of two 1/2 m^2 litter traps under greasewood.	3-29
3.4-6	Seasonal distribution of litterfall over the 16 months of sampling.	3-41
3.4-7	Illustration of cages placed over sagebrush to assess browse utilization.	3-44
3.4-8	Monthly mean moisture contents for 0-5 cm (0) and 5-15 cm (0) soils. All sites are included. Results for 1981-1983 are compared.	3-64

Figure		Page
3.4-9	Average pH values for all sites and depths for 1981-1983.	3-67
3.4-10	Average EC values for all sites and all depths for 1981-1983.	3-68
3.4-11	Yearly cycle of total bacteria for 0-5 cm (O) and 5-15 cm (O) soil depths. All sites are included for 1981-1983.	3-70
3.4-12	Monthly mean fungi value for 0-5 cm (O) and 5-15 cm (O) soil depths. All sites are included for 1981-1983.	3-71
3.4-13	Monthly mean respiration for 0-5 cm (O) and 5-15 cm (O) soil depth. All sites are included for 1981-1983.	3-75
3.4-14	Monthly mean dehydrogenase activities for 0-5 cm (O) and 5-15 cm (O) soil depths. All sites are included for 1981-1983.	3-76
4.3-1	Location of aquatic biology transects in the White River and Evacuation Creek.	4-7
4.3-2	Velocity, final velocity/initial velocity and organic load accumulation.	4-16
4.4-1	Discharge in the White River near Asphalt Wash at Station 6700.	4-19
4.4-2a	Cross-section profiles of White River Transect WR27.	4-20
4.4-2b	Cross-section profiles of White River Transect WR18.	4-21
4.4-2c	Cross-section profiled of White River Transect WR03.	4-22
4.4-3	Interstitial sediment size fractions for White River Transects WR03, WR18 and WR27.	4-27
4.4-4	Total suspended solids data for White River Transect WR18.	4-28
4.4-5	Total suspended solids data for White River Transects WR03, WR18 and WR27.	4-29
4.4-6	Depth to 1% incident light penetration for White River Transect WR18.	4-30
4.4-7	Depth to 1% incident light penetration for White River Transects WR03, WR18 and WR27.	4-31
4.4-8	Water temperatures in the White River near Asphalt Wash at Station 6700.	4-32

LIST OF FIGURES (continued)

Figure		Page
4.4-9	Conductivity in the White River at Transect WR18.	4-32
4.4-10	Conductivity data for White River Transects WR03, WR18 and WR27.	4-33
4.4-11	Total phosphorus, reactive phosphorus total inorganic nitrogen in the White River at Transect WR18.	4-34
4.4-12	Concentration of total inorganic nitrogen for White River Transects WR03, WR18 and WR27.	4-36
4.4-13	Concentration of the forms of inorganic nitrogen compromising total inorganic nitrogen for White River Transects WR03, WR18 and WR27.	4-37
4.4-14	Concentration of total phosphorus for White River Transects WR03, WR18 and WR27.	4-38
4.4-15	Concentration of orthophosphate for White River Transects WR03, WR18 and WR27.	4-39
4.4-16	Total inorganic nitrogen to orthophosphate ratio for White River Transects WR03, WR18 and WR27.	4-40
4.4-17	Benthic organic matter contained in macroinvertebrate samples for White River Transects WR03, WR18 and WR27.	4-43
4.4-18	Sediment organic matter as a percent of the sediment size fraction for White River Transects WR03, WR18 and WR27.	4-44
4.4-19	Periphyton biomass as chlorophyll a for White River Transects WR03, WR18 and WR27.	4-45
4.4-20	Taxonomic richness of benthic macroinvertebrate community for White River Transects WR03, WR18 and WR27.	4-50
4.4-21	Numbers of benthic macroinvertebrates by functional group and totals for White River Transects WR03, WR18 and WR27.	4-52
4.4-22	Calculated biomass of benthic macroinvertebrates by functional group and totals for White River Transects WR03, WR18 and WR27.	4-53
4.4-23	Leafpack decomposition for leafpacks at Transect WR18 in the White River.	4-62
4.4-24	Biomass and species richness of benthic invertebrates in the White River.	4-74

LIST OF FIGURES (continued)

Figure		Page
4.4-25	Numbers of macroinvertebrates found per unit surface area in substrate baskets as a function of available substrate.	4-79
4.4-26	Biomass of macroinvertebrates found per unit surface area in substrate baskets as a function of available substrate.	4-79
5.3-1	Sampling locations on and near Tract Ua and Ub.	5-10
5.3-2	Annual precipitation (water year) and Spring precipitation (April-June) at Utah Oil Shale Tracts Ua and Ub from 1975-1983.	5-11
5.4-1	Soil and vegetation maps of the Greasewood rodent-trapping grids.	5-20
5.4-2	Soil and vegetation maps of the Juniper rodent-trapping grids.	5-21
5.4-3	Soil and vegetation maps of the Shadscale rodent-trapping grids.	5-22
5.4-4	Soil and vegetation maps of the Riparian rodent-trapping grids.	5-23
5.4-5	Abundance of all foliage invertebrates on big sagebrush in 1982 and 1983.	5-42
5.4-6	Biomass, richness and diversity of foliage invertebrates on big sagebrush in 1982 and 1983.	5-43
5.4-7	Abundance of all foliage invertebrates on host plants spiny hopsage, greasewood, spiny horsebrush and shadscale in 1983.	5-46
5.4-8	Abundance of all foliage invertebrates on host plants cottonwood, Utah juniper, rubber rabbitbrush and black sagebrush in 1983.	5-47
5.4-9	Richness of all foliage invertebrates on host plants spiny hopsage, greasewood, spiny horsebrush and shadscale in 1983.	5-48
5.4-10	Richness of all foliage invertebrates on host plants cottonwood, Utah juniper, rubber rabbitbrush and black sagebrush in 1983.	5-49
5.4-11	Abundance of all invertebrates on big sagebrush in four vegetation types in 1982 and 1983 and leaf water potential of big sagebrush in four vegetation types in 1983.	5-52

LIST OF FIGURES (continued)

Figure		Page
5.4-12	Biomass of all invertebrates on big sagebrush in four vegetation types in 1982 and 1983.	5-53
5.4-13	Richness of all invertebrates on big sagebrush in four vegetation types in 1982 and 1983.	5-54
5.4-14	Abundance and diversity of reptiles in Greasewood in June 1981 and 1982.	5-58
5.4-15	Abundance and diversity of reptiles in Juniper in June 1981 and 1982.	5-59
5.4-16	Abundance and diversity of reptiles in Shadscale in June 1981 and 1982.	5-60
5.4-17	Abundance and diversity of reptiles in Riparian in June 1981 and 1982.	5-61
5.4-18	Consuming biomass of the bird community in June from 1975-1983 in four habitats.	5-68
5.4-19	Consuming biomass for the avian community, trophic groups, and select insectivore guilds in Riparian in June 1982 and 1983.	5-69
5.4-20	Consuming biomass for the bird community, trophic groups, and select insectivore guilds in Juniper in June 1982 and 1983.	5-70
5.4-21	Consuming biomass for the bird community, trophic groups, and select insectivore guilds in Greasewood in June 1982 and 1983.	5-71
5.4-22	Consuming biomass for the bird community, trophic groups, and select insectivore guilds in Shadscale in June 1982 and 1983.	5-72
5.4-23	Consuming biomass of three avian trophic groups in June from 1975-1983 in Greasewood and Juniper.	5-73
5.4-24	Consuming biomass of three avian trophic groups in June from 1975-1983 in Shadscale and Riparian.	5-74
5.4-25	Consuming biomass of insectivore guilds in June from 1975-1983 in Greasewood and Juniper.	5-75
5.4-26	Consuming biomass of insectivore guilds in June from 1975-1983 in Shadscale and Riparian.	5-76

Figure		Page
5.4-27	Species richness for the avian community, trophic groups, and select insectivore guilds in Shadscale in June 1982 and 1983.	5-79
5.4-28	Species richness for the avian community, trophic groups, and select insectivore guilds in Juniper in June 1982 and 1983.	5-80
5.4-29	Species richness for the avian community, trophic groups, and select insectivore guilds in Greasewood in June 1982 and 1983.	5-81
5.4-30	Species richness for the avian community, trophic groups, and select insectivore guilds in Riparian in June 1982 and 1983.	5-82
5.4-31	Density, richness and diversity of rodents in Greasewood in August from 1982 and 1983.	5-92
5.4-32	Density, richness and diversity of rodents in Juniper in August from 1982 and 1983.	5-94
5.4-33	Density, richness and diverity of rodents in Riparian in August from 1982 and 1983.	5-95
5.4-34	Density, richness and diversity of rodents in Shadscale in August from 1982 and 1983.	5-97
5.4-35	Density of desert cottontails in four habitats, bimonthly, from 1975-1983.	5-99
6.3-1	Precipitation and Evaporation Monitoring Stations.	6-8
6.3-2	Surface Water Monitoring Stations.	6-9
6.3-3	Location of Water Monitoring Wells.	6-12
6.3-4	Plant Site Wash Retention Dam and Monitoring Wells.	6-14
6.4-1	Annual Precipitation Totals - Water Years 1975-1983.	6-20
6.4-2	Seasonal Precipitation Averages.	6-22
6.4-3	Monthly Precipitation Averages.	6-23
6.4-4	Precipitation Frequencies at ARA-13.	6-25
6.4-5	Water Balance - March 5-July 31.	6-32
6.4-6	Comparison of 1983 Discharge to 1975-1982 Discharge.	6-38
6.4-7	Suspended Sediment Discharge vs Streamflow.	6-41

LIST OF FIGURES (continued)

Figure		Page
6.4-8	White River Drainage.	6-50
6.4-9	1983 Discharge Hydrographs for White River Stations 6395 and 6700.	6-51
6.4-10	Suspended Sediment Discharge vs Streamflow.	6-59
6.4-11	1983 Water Temperature Hydrographs for White River Stations.	6-61
6.4-12	1983 Specific Conductance Hydrographs for White River Stations.	6-63
6.4-13	Distribution of Major Ions during Different Flow Regimes at White River.	6-69
6.4-14	Ground Water Level Hydrograph Mean Daily Water Levels.	6-76
6.4-15	Ground Water Level Hydrograph Mean Daily Water Levels.	6-79
6.4-16	Ground Water Level Hydrograph Mean Monthly Water Levels.	6-80
6.4-17	September 1983 Ground Water Level Hydrograph for Wells G-5 and G-11.	6-82
6.4-18	Static Water Levels in G-Wells - Water years 1979-1983.	6-85
6.4-19	Trilinear Diagram Showing Water Quality Trends at Wells G-5 and G-11.	6-90
6.4-20	Ground Water Level Hydrograph Mean Daily Water Levels.	6-92
6.4-21	Static Water Levels and Specific Conductance in Well AG-6-1.	6-97
7.1-1a	Position in the topoil at Anvil Points where samples were taken for root and chemical analysis.	7-10
7.1-1b	Photo showing actual sampling for roots at Anvil Points.	7-10
7.1-2	Design and layout of seeding and fertilizer treatments on topsoil storage pile.	7-32

LIST OF FIGURES (continued)

Figure		Page
7.1-3	Photo showing the design and initial establishment of test plots on topsoil storage pile.	7-33
7.1-4	Design and layout of interplanting and interseeding study at Section 6, Bonanza, Utah.	7-37
7.1-5	Roots in Linium lewisii found growing throughout the circular grate processed shale.	7-49
7.1-6	One of six growth seedlings flats illustrating the general performance of the selected species in a randomized design.	7-49
7.1-7	Hedysarum boreale indicating stress as shown about the leaves after 113 days in circular grate processed oilshale.	7-52
7.2-1	The discharge patterns for the White River between 1980 and 1982.	7-62
7.2-2	The location of the White River and the Federal Lease Tracts Ua-Ub.	7-66
7.2-3	The distribution of metal concentrations in precipitates collected at different sites from the White River.	7-73
7.2-4	The distribution of metal concentrations in fine detritus from sediments collected at different sites from the White River.	7-74
7.2-5	The distribution of metal concentrations in fish collected in the White River.	7-76
7.2-6	The distribution of metal concentrations in algae collected in the White River.	7-80
7.2-7	The distribution of metal concentrations in coarse detritus collected in the White River.	7-82
7.2-8	The distribution of metal concentrations in macroinvertebrates collected in the White River.	7-83
7.2-9	Cross-section profile and velocity contours of WRSOC monitoring Transect WR18.	7-86
7.2-10	The concentration of metals in macroinvertebrates at four sites in the White River.	7-89

Figure		Page
7.2-11	The natural phonomena which may affect the concentrations of heavy metals in natural environments.	7-91
7.2-12	The relationship between dissolved copper concentrations and time in the presence of precipitating $CaCO_3$.	7-94
7.2-13	The relationship between the initial copper concentration and the amount of copper precipitated from White River water.	7-95
7.2-14	The effect of initial copper and suspended solids on the 24 hr equilibrium dissolved Cu and the effect of initial zinc and suspended solids on the 24 hr equilibrium dissolved Zn.	7-100
7.2-15	The effect of pH on the equilibrium level of Cu and Zn during field experiments.	7-101
7.2-16	Adsorption vs time for three levels of Pb and Zn during field experiments.	7-103
7.2-17	The trophic level accumulations for the selected heavy metals studied in the White River.	7-106
7.2-18	The relationship between macroinvertebrate metal content and precipitate metal content.	7-109
8.1-1	Conceptual diagram of ecosystem organization.	8-4
8.1-2	Diagram of WRSOC environmental program organization.	8-5
8.2-1	Sample library coding sheet.	8-9
8.4-1	Daily precipitation totals at precipitation gage ARA-13.	8-19
8.4-2	Mean daily temperature at weather station A-13.	8-20
8.4-3	Cumulative daily wind speed at weather station A-13.	8-21
8.4-4	Mean daily relative humidity at air quality station A-6.	8-22
8.4-5	Net solar radiation at air quality station A-6.	8-23
8.4-6	Results of clustar analysis for nine precipitation gage locations.	8-31

INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this report, "1983 Progress Report Environmental Program White River Shale Project," is to present the results of ambient environmental monitoring and reclamation research activities associated with the development of Federal Prototype Oil Shale Lease Tracts Ua and Ub located in northeastern Utah. With the exception of the water resources section, this report covers monitoring studies conducted during calendar year 1983. The water resources section is based upon the 1983 water year (i.e., October 1, 1982 through September 30, 1983).

1983 represented the ninth continuous year of ambient environmental monitoring and reclamation research conducted for the White River Shale Project (WRSP). During this period of time, baseline environmental conditions have been characterized and are generally defined as those range of values noted between program initiation in late 1974 and the end of the 1981 monitoring year. 1983 also represents the second year of construction related activities at the WRSP and thus the monitoring program is providing data with which to assess the impacts of development on the tracts.

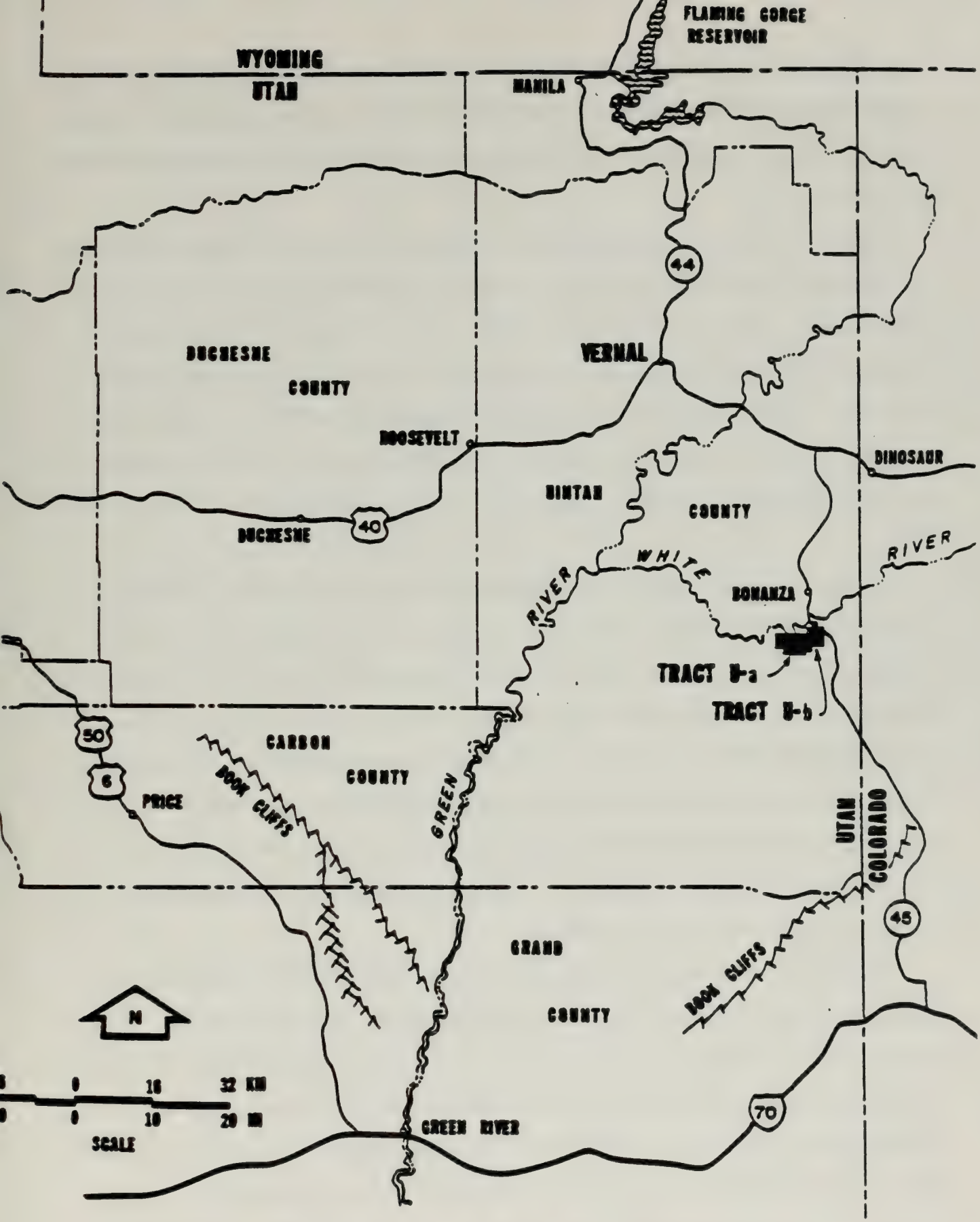
1.2 BACKGROUND

The White River Shale Project (WRSP) was established in 1974 to plan for and implement the joint development of Tracts Ua and Ub. Each tract encompasses 5120 acres of federal land. Figure 1.2-1 shows the location of the leased lands. The lease to Tract Ua is held equally by Phillips Petroleum Company and Sun Shale Oil Company. The lease to Tract Ub is held by Sohio Shale Oil Company.

The White River Shale Oil Corporation (WRSOC), in its agency relationship to the lessees of Tracts Ua and Ub, has been retained to manage development of the WRSP. Thus, the WRSOC is responsible for implementation of environmental monitoring requirements mandated by the oil shale leases. Environmental monitoring programs for the WRSP are conducted by independent environmental consulting firms under contract to the WRSOC.

Four significant environmentally oriented tasks have been completed for the WRSP since work under the leases began in 1974. First, the "Detailed Development Plan" or DDP, required by lease provision was submitted to the Department of Interior - Oil Shale Office in June, 1976 and subsequently revised, updated, and resubmitted in September, 1981. This plan describes the schedule, activities, and expected results associated with planning, construction, operation and abandonment of a commercial oil shale processing facility on Tracts Ua and Ub. The DDP was approved in March, 1982 following the lifting of a court-imposed injunction which had suspended tract development since May, 1977.

Second, the lease-required two-year environmental monitoring and data collection program was completed for the WRSP in January, 1977. The results of this significant effort were published in October, 1977 as the "Final Environmental Baseline Report." Annual "Progress Reports," such as this document, have been prepared in subsequent years (1977-1982) to present data from the WRSP's on-going monitoring program which update environmental conditions on the lease tracts. Monitoring continued during the period from May, 1977 through March, 1982 in



PROJECT LOCATION MAP
TRACTS U-a & U-b

FIGURE
1.2-1

order to confirm observations made during the Baseline period, evaluate environmental trends apparent only through multi-year study, track ambient ozone levels over an extended period and evaluate more refined biological resources monitoring techniques.

Third, to develop a technology for revegetating disturbed sites and reclaiming processed shale disposal areas, a study was conducted on behalf of the WRSP from November, 1974 through December, 1978. The final report, "Revegetation Studies for Disturbed Areas and Processed Shale Disposal Sites," was published in June, 1979. The WRSP reclamation research program has continued and the annual progress reports have provided updated information on the results of research studies supported by the WRSP. Section 7.1 of this report updates this area for 1983.

Fourth, as tract development progressed into the construction stage (and subsequently into operation) it became apparent that the WRSOC must establish a monitoring pholosophy based upon an acquired understanding of the tract ecosystem to guide the future WRSP monitoring program. Thus, in June, 1982 the "White River Shale Project Environmental Monitoring Manual" was published which established a detailed environmental monitoring program for the WRSP that will track the impacts of project development, evaluate the success of our planned mitigation measures, and provide feedback to design and operations to minimize and correct any identified adverse effects.

Construction is now in progress at the WRSP and monitoring is proceeding according to the plan established by the Environmental Monitoring Manual, as revised. Construction activity at the site during 1983 included the continuation of infrastructure development (including service buildings, water and wastewater treating facilities, power distribution and communication facilities), continuation of excavation on the production decline, initiation of excavation on the vertical air ventilation shaft, and completion of construction on the runoff

retention dam and pond downgradient of the plant site. Substantial topsoil-like material has been stockpiled for use in future reclamation activities and revegetation of certain disturbed areas on tracts have been initiated.

1.3 SUMMARY OF RESULTS

Monitoring of environmental conditions on and near to the WRSP has been a continuous activity since late 1974. The 1983 ambient environmental monitoring program involved six major disciplines including air resources, vegetation resources, aquatic biology, terrestrial fauna, water resources and reclamation research. Work also began to integrate information generated within these disciplines and to refine the overall WRSP monitoring program. This initial effort is entitled "Ecosystem Analysis." A principal goal of the 1983 monitoring program was to continue investigation of tract development related impacts. The following summarizes the results of the 1983 program.

The air resources monitoring program during 1983 continued with macrometeorology measurements at five sites and air quality measurement at two sites. No major changes were made to the program during the year. Site A4 south of the tracts continued to function as the primary background station after assuming that role from Site A6 during 1982 following the initiation of construction activities on tract.

Meteorologically, as well as climatologically, 1983 was an unusual year. The summer was accompanied by lower winds with less turbulence, lower temperatures, higher humidities and less net radiation than normal. The winter was accompanied by increased storminess as seen in lower average barometric pressure and higher relative humidity.

Air quality at the WRSP during 1983 was generally comparable to values measured during the baseline period and reflect conditions typical for a remote rural area. As in previous years, ozone and total suspended particulate (TSP) concentrations exhibited a natural, non-zero background level. The peak 24-hour ozone level, during 1983 was 142 $\mu g/m^3$ compared to the national standard of 235 $\mu g/m^3$ and a peak baseline value of 163 $\mu g/m^3$ measured in May, 1977. The maximum 24-hour average TSP levels at sites A4 and A10 during the year were 71.9

$\mu g/m^3$ and 74.7 $\mu g/m^3$, respectively. These levels occurred the same day on which the winds were high; however, they are only about 50 percent of the national secondary standard and about 60 percent of the previous maximums measured on tract. All other measured parameters (CO, SO_2, and NO_x) were present at levels approaching the lower limit of detection. Peak CO levels reached 25 percent of the eight-hour standard due probably to zero drift problems with the instrument.

Sound level measurements continued at six sites. Background sites recorded near-baseline levels of 20-40 dB(A) at remote sites and 20-50 dB(A) near the White River. Sites impacted by construction measured up to 75 dB(A).

Precipitation in 1983 was above average at the WRSP monitoring sites. Annual precipitation for the water year ranged from 11.5 inches at the plant site (ARA-13) to 14.9 inches south of the tracts (RA-4) and averaged 13.7 inches for the 10-station network. While the 1983 precipitation total was the second highest recorded by the WRSP monitoring program, no unusual precipitation intensities were measured. The most intense rainfall event of the year was representative of a two-year return interval storm. Total pan evaporation for the freeze-free period of May through September was similar to previous measurements at 24.37 inches. This data was collected at a new site (EVP-9) in Upper Southam Canyon which was relocated during 1983 to coincide with sites used for biological data collection.

Mean annual streamflow at White River station 6700 below Asphalt Wash during 1983 was the highest observed during the 9 year history of the WRSP monitoring program. In fact, the 1983 annual streamflow was the second highest for the complete period of record (1924-1979) based upon data from station 6500 on the White River near the Ignatio Bridge. High flows in the White River occurred from late-May through early-August due to upper basin runoff associated with an unusually heavy snowpack in the mountains. The 1983 annual runoff at station

6395 (stateline) was 818,862 acre-feet compared in the long-term average of 502,300 acre-feet for this site. The daily discharge at station 6395 during 1983 varied from 220 cubic feet per second (cfs) to 5820 cfs.

Suspended sediment levels and several water quality parameters measured at station 6700 were above previously observed values. However, it was concluded that the higher values were natural occurrences related to high snowmelt conditions not previously encountered during the monitoring program. The only significant difference in water quality between concurrent samples collected at station 6395 above the tracts and station 6700 below the tracts was attributed to an incidence of runoff from Evacuation Creek, located between the two White River stations, containing high total dissolved solids.

Annual streamflow at station 6430 near the mouth of Evacuation Creek exceeded the mean discharge for the 8-year record of the WRSP monitoring program for that station by a factor of five. The high streamflow was the direct result of high snowmelt and numerous intense summer thunderstorms in the Evacuation Creek drainage basin. Suspended sediment and water quality data for station 6430 were typical of previous records.

Drywash monitoring continued at the plant site (station 6602), the mouth of Southam Canyon (station 6610), and the mouth of Asphalt Wash (station 6625). Station 6605 in upper Southam Canyon at the southern boundary of Tract Ua has been reactivated and operated throughout 1983. With completion of the runoff retention dam and pond drainage area above station 6602 was reduced substantially. Annual runoff from Southam Canyon at station 6610 was near the mean for the 8-year WRSP monitoring program. However, a peak flow measurement resulting from one summer thunderstorm resulted in the highest recorded flow event of the program (440 cfs). Surface flow at station 6625 was well below the mean for the total program. Water quality records from the dry washes did not show changes from previous values.

Biological resource monitoring continued during 1983. The program included evaluation of vegetation resources, aquatic biology and terrestrial fauna. The WRSOC also continued to sponsor reclamation research activities during 1983 as well.

The vegetation monitoring program included nine interrelated tasks designed to document existing conditions, discern interactions between biotic and abiotic factors relating to vegetation, and evaluate impacts of development and reclamation success. Production of annual plant biomass was very high during 1983, being exceeded only by levels measured in 1975. Production and annual cover values ranged from 1.2 g/m^2 and 0.4% for juniper areas to 116.4 g/m^2 and 14.9% for riparian areas.

Growing conditions for sagebrush during 1983 were very good as reflected in higher than average stem growth. Animal use of sagebrush assessed by the Cole Browse Survey showed minimal use. Overall animal use of shrubs was substantially lower in 1983 (18% use) than in 1982 (51% use).

In other vegetation studies, sagebrush leaders were analysed for nine trace elements expected to be associated with WRSP operations. All values showed levels within the normal range of concentrations for desert plants. Litterfall measurements continued during 1983. Litterfall was highest for shadscale and lowest for fourwing saltbush. Aerial color infrared photographs were taken at 1:2400 along three transects to evaluate plant condition and stress. Data from 1982 and 1983 were not measureably different and establish a good baseline for future efforts.

Lichen monitoring continued at 21 permanent stands located along three transects radiating from the plant site. Parameters found to be good indicators of current conditions and potentially valuable for monitoring impacts include total cryptogamic cover, number of species/quadrat, and frequency of eight key lichen species.

Soil microbiology and soil chemistry analyses continued at eight sites within the four principal vegetation types occurring on tract. Correlations between chemical and microbiological factors were identified. Namely, high bacterial counts, total fungi, dehydrogenase, and microbial respiration levels were associated with moist soils while bacterial numbers and activities tended to be positively correlated with organic matter.

Also, during 1983 several monitoring sites were established along the tract access road between Duck Rock and the plant site to evaluate the success of revegetation efforts which began in 1982. The revegetation program involved the use of both seeding and transplanting techniques. An initial survey of transplants in June, 1983 showed 85% survival with sagebrush survival the highest (96%) and rabbitbrush the lowest (50%). However, because of high herbivore populations, by October survival of sagebrush had declined to 36% and no living transplants of fourwing saltbush, rabbitbrush or shadscale were located along any transect.

Seeding success during 1983 was excellent. The average density in October of all plots on all sites was 9.6 plants/m^2 which is classified as excellent for the Intermountain area. Sagebrush was the most common species, followed by western wheatgrass and fourwing saltbush. Seeding success can be attributed to favorable moisture conditions during 1983.

Aquatic biology monitoring continued during 1983 in the White River. Experiments were conducted to define the variability of important parameters to determine if cross-stream transects were statistically appropriate to characterize riverine conditions. Experiments were also undertaken to increase the program's sensitivity to macroinvertebrate parameters.

Due to elevated flows in the White River during 1983, river habitats changed significantly. WRSP transect WR27 below Asphalt Wash was altered from a shallow riffle to a deep, swift run. Instantaneous water quality parameters, particularly nitrogen and phosphorus nutrients, were elevated over values noted in 1981

and 1982. Primary production was severely limited due to the low levels of light penetration during much of the year. Comparisons of biological parameters for control (WR03) and treatment (WR18) sites showed that chlorophyll a and macroinvertebrate numbers and biomass were not significantly different and thus were responding similarly. WR27, due to its altered state, was different from both upstream sites.

A metals study was also conducted in the White River adjacent to the tracts for the purpose of establishing a baseline for this parameter. Further, the study also investigated the mechanisms regulating heavy metals' dynamics in the White River. The study showed high natural metal levels in the river existing at this time, a spatial correlation between river and alluvial water quality, adaption of organisms in the river to high metal loadings, and that adsorption of metals by suspended sediments is a major natural mechanism for removal of metals from the soluable form.

In the terrestrial fauna program, four major groups were sampled in 1983. These included foliage invertebrates, reptiles, birds, and mammals. In addition a special study was begun to detail interrelationships among vegetation, soils, seed production and rodent abundance and distribution.

Foliage invertebrates showed a significant increase from 1982 to 1983 on big sagebrush and varied with soil water potential. Four various host plants variations in invertebrate richness and diversity were related to leaf water potential. Variations in reptile species values were inversely related to annual plant productivity at individual sampling sites. No impacts due to the project were noted on reptile populations.

Five aspects of the bird community were studied during 1983 including spring migratory birds, breeding birds, waterfowl, raptors, and endangered species. Twenty active raptor nests were located during the year as compared to 12 nests in 1982. Golden eagles (seven active nests) and red-tailed hawks (seven active

nests) were the most common breeders in 1983. Breeding success was very high for all species due probably to abundant food (i.e., desert cottontails and montane voles) and moderate temperatures. During surveys along the White River in February, 1983, 26 bald eagles were counted versus 10 in 1982.

Thirty three species of mammals were noted during 1983 surveys. Rodent populations did not change appreciably at most trapping sites. Montane voles were found in abundance on alluvial deposits near the White River while previous year's surveys produced only limited sitings. Mule deer were more common in 1983 than in previous years, but populations remain relatively low. Bighorn sheep were observed for the first time since monitoring began in 1974 near Asphalt Wash and near Ignatio Bridge.

Reclamation research conducted in 1983 continued at sites previously established at Anvil Points, Colorado and at the WRSP Section 6 study site. Topsoil related research was initiated on a large topsoil stockpile near the mine services building at the plant site. A report is also included on laboratory and greenhouse studies on circular grate processed shale initiated in late 1982. The WRSP research program is intended to support WRSP's plans for reclamation of disturbed areas and processed shale.

The Anvil Points studies continued to show successful establishment of plants on processed shale. Root growth into processed shale continued with no significant differences between root volumes in topsoil samples and those in processed shale. Plant survival in the fifth year of study at Anvil Points remains high. Both plant height and cover values were higher in 1983 than previous years. Annual plant succession studies which had shown promising results were discontinued at Anvil Points as the site was disturbed by construction activities.

Studies continued at Section 6 to investigate habitat enhancement through interplanting and interseeding. High herbivore populations caused substantial

losses for unprotected plants. However, for those plants protected by an artificial covering, survival exceeded 99%.

Topsoil studies at the plant site consisted of testing seeding success with various fertilizer application rates. Information gathered will be important for erosion control and stockpile stabilization and for the maintenance of important soil biological characteristics.

During 1983 the WRSOC initiated an internal effort entitled Ecosystem Analyses which was intended to integrate information generated by the five primary monitoring disciplines and to maintain overall program focus on identification of project impacts. Because of limited time and resources, ecosystem level analysis conducted during 1983 focused on the identification and testing of relationships among climatic, pedogenic (soil), and certain floristic parameters. This work is preliminary and will be subject to expansion during 1984. Our expectations are that, through this coordinated effort among WRSOC and its environmental consultants, a stronger and more effective monitoring program may be implemented at the WRSP.

AIR RESOURCES

2.0 AIR RESOURCES

2.1 INTRODUCTION

2.1.1 Program Objectives

The air quality on Tracts Ua and Ub has been monitored continuously by AeroVironment Inc. under contract to WRSP since data collection began in 1974. The initial objectives of this program were:

- To characterize the air quality environment in the vicinity of the tracts in sufficient detail to provide a complete description of the baseline situation against which future air quality could be compared.
- To describe the meteorological environment in the vicinity of the tracts in sufficient detail to provide input data for modeling to simulate the dispersion of air pollutants that would be generated by future developments on the tracts.

Additionally, due to legal complications which delayed the start of construction until mid-1982, a third objective was added:

- To determine the year-to-year variation in the baseline air quality and meteorology of the area in order to see whether the initial two years of measurements adequately represented the ambient conditions.

With the initiation of construction activities on Tracts Ua and Ub in 1982, ambient levels of particulates and gaseous pollutants were expected to change. Thus, the air resources monitoring program took on new objectives:

- o To quantify the air quality impacts of various levels of oil shale development and operation on Tracts Ua and Ub;
- o To demonstrate that impacts of the air contaminants emitted by the facilities are in compliance with the National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act, as well as with Utah air quality standards;
- o To identify areas where additional control of air contaminant emissions would be appropriate or necessary;
- o To continue observing the long-term evolution of regional air quality;
- o To continue monitoring the meteorological environment to provide additional data for future modeling efforts as well as to monitor meteorological events (such as frontal passages) that might affect the regional air quality.

A Development Monitoring Program has been designed to achieve these objectives and is presented in the Environmental Monitoring Manual (White River Shale Oil Corporation, 1982). Monitoring activities since 1982 followed those described in the Environmental Monitoring Manual and marked the transition from the Baseline to the Development Monitoring Program.

2.1.2 Program Evolution

At the beginning of the air monitoring program, a rather extensive measurement network was established. This network included eight stations measuring both air quality and meteorology and four others with only meteorology. Four of these 12 stations were located on the tracts,

with the other eight surrounding the tracts up to two miles away. This intensive siting gave a very thorough definition of both the air on site and that being transported in and out of the tract boundaries.

The first full year (1975) of air quality monitoring showed that the air over the tracts was quite homogenous. This finding was not surprising due to the lack of existing sources. Therefore, in May 1976, the number of stations was reduced to one combination air quality and meteorology site (A6) and three auxiliary meteorology stations (the existing sites at A4 and A11 and a new site at A13). This configuration remained unchanged until 1982.

In the summer of 1982, some construction activities (site preparation, mine development and road improvements) were begun. This activity dictated changes in the monitoring program in accordance with the Environmental Monitoring Manual. Air quality impacts, especially dust related, were expected during construction. To measure these impacts, monitoring of TSP and wind was initiated at station A10. This station was chosen as representative of the area of maximum impacts during drainage conditions (a situation of high pollution potential).

It was important to maintain monitoring of the background air quality concurrent with monitoring of potential impacts. This task had previously been accomplished at station A6, but construction activities very close to this station were biasing the data. Therefore, the background air quality measurements were transferred in mid-1982 to station A4, a site further away and not downwind from the activity. In the following sections of the report, it should be noted that the analysis of background particulate air quality switches from A6 to A4

in April 1982, and background gaseous air quality in July 1982. A statistical analysis of three months of overlapping ozone data at both sites in the 1982 annual report showed strong correlation of the data at both sites, which supported our hypothesis that the background air quality should be the same for the whole area. Meteorological measurements were continued at A6, since meteorology is not affected by construction.

There were only minor changes to the monitoring program in 1983. The mechanical weather station at Site A10 was replaced with an electronic weather station. The previous station measured wind speed, wind direction, and temperature, whereas the new station measures just wind speed and wind direction. Therefore, there are only two and one-half months of temperature data for Site A10 for 1983. Also, there are some changes in the analysis format of this section from previous annual reports. The main change lies in the definition of "baseline" period. Previous reports have defined the initial two (lease-stipulated) years of 1975 and 1976 as "Baseline," with the years 1977 through 1981 termed "Interim." Starting with this report, the whole period of 1975-1981 will be considered "Baseline" since basically no activity took place on the tracts in these years. This period will give a broader base with which to compare any impacts that may be observed during the Development period and, eventually, during Operation.

The monitoring program and data collected in the years 1974 through 1982 are described and summarized in other reports (White River Shale Project Reports, 1976 through 1983; Detailed Development Plan, 1981; and PSD Permit Application, 1981). This section describes the monitoring program in 1983. It discusses the data collected during the year and relates these data to comparable data for the baseline period.

2.2 SUMMARY

Monitoring continued at the five air quality/meteorology and six sound sites through 1983. No major changes were made to the program in this year. Some problems associated with the transfer of the background air quality measurements to A4 still existed but were solved during the year. These included CO analyzer zero drift problems, high-volume platform overcrowding, and an incorrect SO_2 altitude correction factor. Data capture exceeded PSD requirements for all parameters monitored.

Air quality concentrations measured in 1983 were similar to those of previous years. Ozone and particulates were present in the highest quantities, approaching 60 and 50% of their respective short-term NAAQS. All other major pollutants (CO, SO_2, and NO_2) were present at values less than 10% of their applicable NAAQS for all averaging times, except for the eight-hour CO concentration. The peak CO eight-hour average was 25% of the NAAQS, higher than any similar values monitored in previous years. These high CO values may partially be due to zero drift problems associated with a change of instrument at A4 shortly before these values were observed, but could also be related to the increase in traffic and mining equipment on the tracts for project development.

Meteorologically, 1983 was an abnormal year. Major pressure systems that govern the weather pattern were weaker and/or "out of location," leading to unusual conditions. The summer had lighter winds with less turbulence, lower temperatures, higher humidities and less net radiation. The winter was closer to normal, but did have increased

storminess as reflected by the lower average barometric pressure and higher relative humidity.

The air quality and meteorology are closely connected, although the complexity of the relationship makes exact cause/effect predictions difficult. For example, the diurnal distribution of ozone in July 1983 showed less variation than usual, possibly due to increased frontal passages (bringing ozone from aloft) and decreased solar radiation (from more clouds). It is also possible that the wetter conditions and lower wind speeds in summer mitigated dust impacts from the construction activities. These relationships will continue to be investigated as the program continues and when impacts occur.

2.3 PROGRAM DESCRIPTION

During 1983, gaseous air quality was measured at one site, particulates at two, and meteorology (wind and temperature) at five sites. The site locations and parameters measured at each of the sites are shown in Figure 2.3-1. All parameters shown were monitored for the full year, except for temperature at A10 which was removed in March 1983.

2.3.1 Air Quality Monitoring Program

Table 2.3-1 lists the instruments used to monitor the air quality parameters during 1983. All instruments comply with EPA regulations. This table also gives the lower detection limits, data precisions and lower validity limits of all the instruments. All parameters, except total suspended particulates, are monitored continuously. Data are recorded in one-minute averages on cassette tapes and on multipoint strip charts every two minutes. Total suspended particulates were measured over a 24-hour period daily from January 1, 1983, through September 5, 1983, at Sites A4 and A10. From September 6 through December 31, 1983, samples were taken every third day. Additionally, a collocated sampler at Site A4 took samples every sixth day.

The percentage of time each air quality parameter was monitored on Tracts Ua and Ub in 1983 is presented in Table 2.3-2. For TSP, the calculation was based on the designated TSP samplers and not the collocated sampler. Although within PSD guidelines, the NO_2 data capture is somewhat lower than normal due to instrument malfunction during a few weeks in spring and several weeks in the fall.

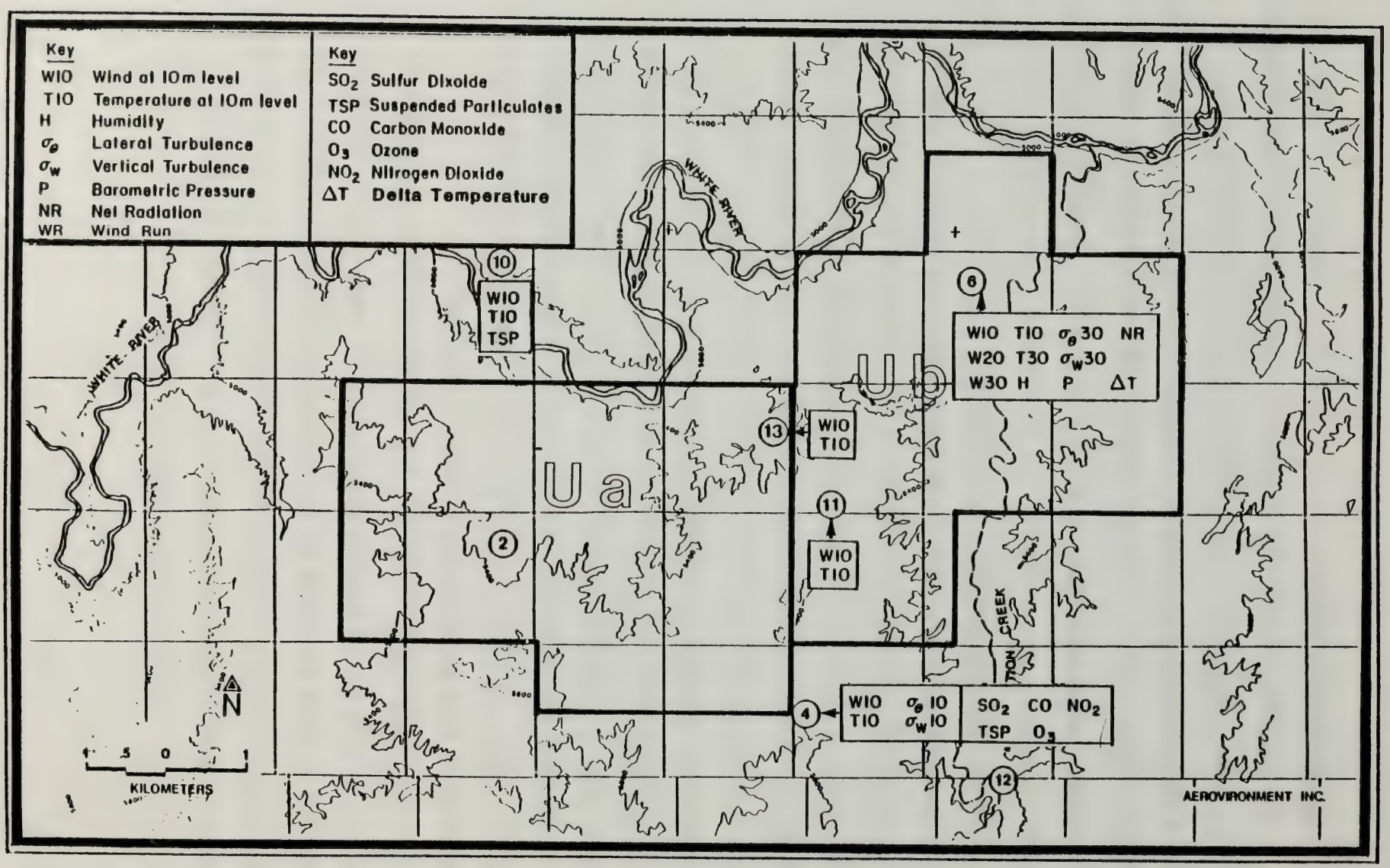


FIGURE 2.3-1. Locations of meteorological and air quality measurement stations on Tracts Ua and Ub during 1983.

TABLE 2.3-1. Air quality monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1983.

Parameter	Monitoring Instrument	Instrument Lower Dectection Limit	Data Precision	Lower Limit of Data Validity
O_3	Monitor Labs Model 8410E ozone analyzer, chemiluminescence	2 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
CO	Monitor Labs Model 8310 infrared	0.1 mg/m^3	0.1 mg/m^3	0.1 mg/m^3
NO_x	Monitor Labs Model 8440E NO/NO_x analyzer, chemiluminescence	5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
NO		5 $\mu g/m^3$	6 $\mu g/m^3$	6 $\mu g/m^3$
$NO_2(NO_x-NO)$		5 $\mu g/m^3$	12 $\mu g/m^3$	12 $\mu g/m^3$
SO_2	Thermo Electron Corp. Model 43 pulsed fluorescent SO_2 analyzer	25 $\mu g/m^3$	8 $\mu g/m^3$	25 $\mu g/m^3$
TSP	Sierra Instruments Model GMWC-2000H, Hi-Vol with constant flow	0.5 $\mu g/m^3$	+ 6% of Toad or 1 $\mu g/m^3$	1 $\mu g/m^3$

TABLE 2.3-2. Percentage of time air quality parameters were monitored during January 1 - December 31, 1983.

Station	Component	Percentage of Time Monitored in 1983
A4	SO_2	99
	NO_2	85
	O_3	100
	CO	100
	TSP	93
A10	TSP	93

2.3.2 Meteorological Monitoring Program

Table 2.3-3 lists the meteorological monitoring equipment used. Meteorological data are collected continuously and recorded on cassette tapes. Strip charts are also used at Sites A4, A6 and A10 for backup records. Table 2.3-4 lists the percentages of data recovered for each meteorological parameter monitored on the tracts.

The barometric pressure instrument for Site A6 was damaged during an electrical storm in July and was out for repair until November 1983. The sigma theta instrument at Site A6 had an electronics problem in July but was back in operation the second week of August. The sigma w instrument at A6 was not operating for the first six months of 1983. The propellor blades on the sigma w instrument were broken in December, 1982 possibly due to snow. The propellor was fixed in April, however, then a sensor became defective and the instrument was out for repair till June. The sigma w instrument at A4 had a frozen propellor for part of January and February and subsequent sensor and bearing problems during the summer.

The mechanical weather station at Site A10 was replaced with an electronic weather station in mid-March due to frequent problems. For instance, the mechanical weather station was not operating during the first three weeks of January 1983 due to chart failure. The new electronic weather station only records wind speed and wind direction, not temperature, as was previously measured with the mechanical weather station. Therefore, data capture in Table 2.3-4 for temperature at Site A10 is based on approximately ten weeks of monitoring. The chart

TABLE 2.3-3. Meteorological monitoring equipment by parameter and the instrument lower detection limit, data precision, and lower limit of data validity during 1983.

Parameter	Monitoring Equipment	Instrument Lower Detection Limit	Data Precision	Lower Limit of Data Validity
Wind Speed	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6)	1 m/s	0.2 m/s	1 m/s
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	1 m/s	0.2 m/s	1 m/s
Wind Direction	Meteorology Research Inc. Model 1022 anemometer (Sites 4, 6)	N/A	5%	N/A
	Meteorology Research Inc. Model 1071 anemometer (Sites 11, 13)	N/A	5°	N/A
Temperature	Meteorology Research Inc. Model 840 thermistor (Sites 4, 6, 10)	$-30^{o}C$	$0.5^{o}C$	$-30^{o}C$
	Meteorology Research Inc. Model 1071 thermistor (Sites 11, 13)	$-34^{o}C$	1°	$-34^{o}C$
Delta Temperature	Meteorology Research Inc. Model 840 thermistor	N/A	$0.2^{o}C$	1°
Sigma Theta	Meteorology Research Inc. Model 1022 with sigma processor	0.5^{o}	1°	N/A
Sigma W	R.M. Young Model 27100, with AV sigma processor	0.05 m/s	0.05 m/s	0.05 m/s
Barometric Pressure	Science Associates No. 370	600 mm Hg	0.5 mm Hg	600 mm Hg
Net Thermal Radiation	Fritschen net radiometer	-0.40 Ly/min	0.05 Ly/min	-0.40 Ly/min
Relative Humidity	WeatherMeasure Inc. H321-S	0%	5%	5%

TABLE 2.3-4. Percentage of data recovered for meteorological parameters during January 1 - December 31, 1983.

Station	Component	Percentage of Time Monitored in 1983
A4	Wind (10 m)	99
	Temperature (10 m)	85
	Sigma theta (10 m)	98
	Sigma w (10 m)	72
A6	Wind (10 m)	100
	Wind (20 m)	99
	Wind (30 m)	97
	Temperature (10 m)	100
	ΔTemperature (30-10 m)	100
	Relative Humidity	100
	Sigma theta (30 m)	91
	Sigma w (30 m)	57
	Net thermal radiation	85
	Barometric pressure	63
A10	Wind (10 m)	92
	Temperature (10 m)	70*
A11	Wind (10 m)	100
	Temperature (10 m)	96
A13	Wind (10 m)	73
	Temperature (10 m)	82

*Thermometer was removed March 14, 1983, so percent is based on ten weeks of operation.

recorder for wind speed and direction at Site A13 was broken for approximately three months during the beginning of the year.

2.3.3 Sound Level Measurement Program

Sound level measurements are made weekly at locations shown in Figure 2.3-2. The equipment used is a Brüel R. Kjaer type 2225 integrating sound level meter.

2.3.4 Quality Assurance/Quality Control Program

The internal quality assurance program, including procedures for quality control and standard site operating procedures, are described in depth in the "Quality Assurance Plan for Air Resources Monitoring, Oil Shale Lease Tracts Ua-Ub" (AV-QA 8047R2, Aerovironment Inc., 1982).

In 1983, four quarterly performance audits were executed, on January 17-21, April 6-7, July 11-15, and October 4-6. Other than the usual instrument mechanical failures, the only major problem, discovered during one of the audits, was the shift of the station calibration oven temperature from $50^{o}C$ to $44^{o}C$. This shift affected the SO_2 permeation rate output, giving a lower than expected concentration. The temperature problem was corrected by the site technician and the calibration factors adjusted to account for the lower SO_2 output.

During March of 1983, Rockwell International's Environmental Monitoring and Services Center conducted a performance audit of the A4 station at the request of EPA Region VIII. The audit results for the CO and O_3 analyzers were less than 5% different from the expected values. The SO_2 result was approximately 19 percent off. The allowable out-of-specification tolerance is $\leq \pm 15$ percent. The cause of the discrepancy was later identified as an incorrect altitude correction factor

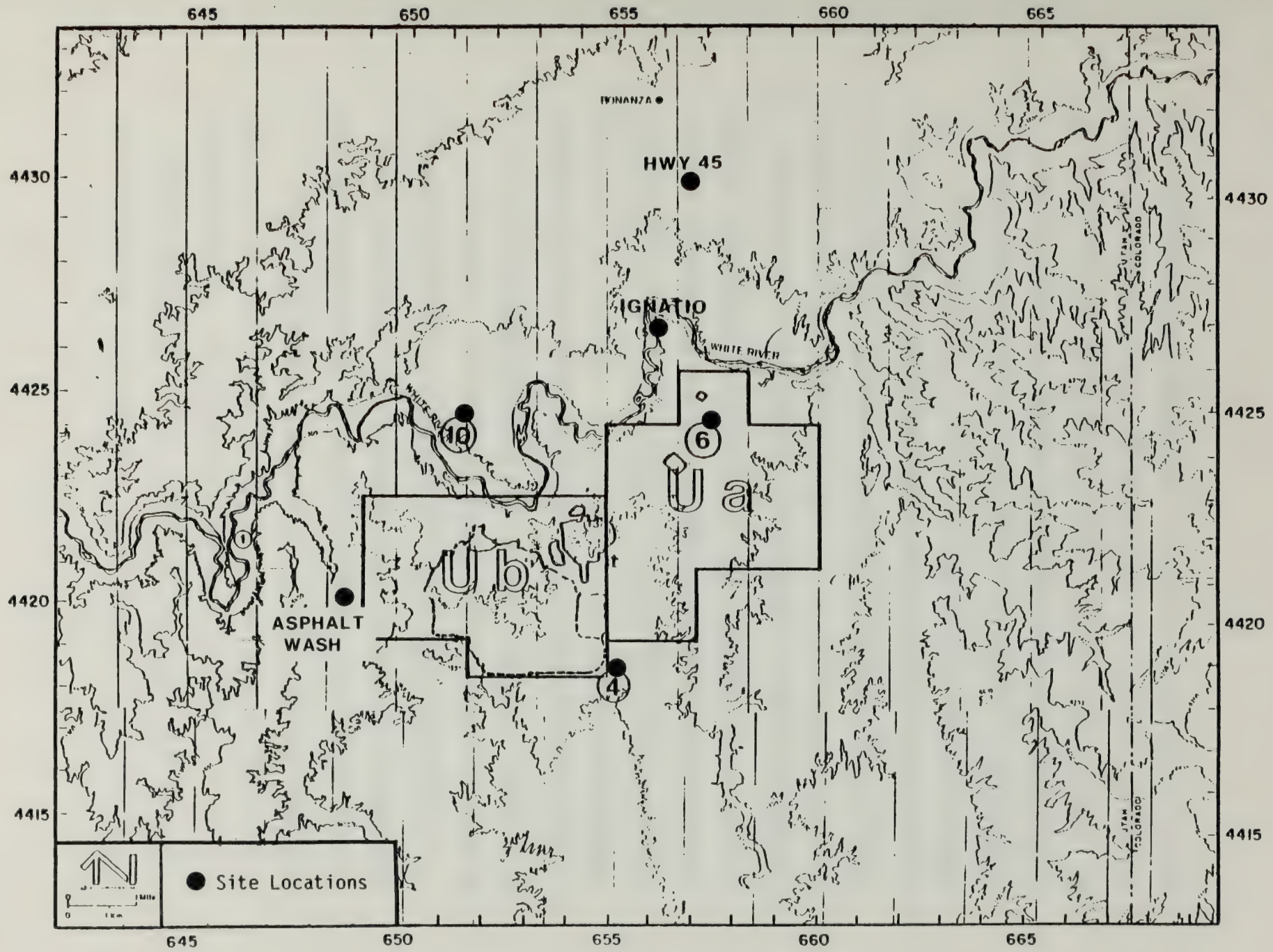


FIGURE 2.3-2. Sound level measuring sites.

used in calculating the stations' concentrations by the site technician. The correct factors, which improved the SO_2 results to within 4 percent, were sent to Region VIII in a letter explaining the problem. The NO/NO_x analyzer was not operating during the external audit due to failure of the chopper drive motor. The analyzer was replaced with the one from Site A6 shortly thereafter.

During the system audit portion of the external audit, several comments and recommendations were made. The sample inlet probe was found to be situated too low. A new, longer sampling cane was constructed and shipped to the A4 site. Also, the A4 shelter roof contained five high-volume samplers, creating a crowded and undesirable situation. Since then, two of the high-volume samplers have been removed. It is planned to enlarge the platform for the particulate samplers to further increase their spacing.

These site problems and the SO_2 discrepancies were associated with the transfer of background air quality monitoring from Station A6 to A4 and are considered normal start-up problems.

AeroVironment asked to participate in the U.S. EPA National Performance Audit Program for CO and particulates. Arrangements were made, but we were unable to participate because all audit equipment and materials were received after the deadline for participation.

2.4 PROGRAM RESULTS AND ANALYSIS

2.4.1 Air Quality

In general, the background air quality on the tracts was typical for a remote rural area. The only pollutants present in any quantity were ozone and particulates, which often have a natural non-zero background level. Except for occasional spurts, possibly due to construction activities, all other instruments measuring pollutants were recording at their threshold limit most of the time, the same situation as found during the baseline period.

The 1983 air quality data were compared with the baseline data (1975-1981) to determine if construction activities have caused any air quality impacts. Generally, the 1983 data are within the range of values observed during the years with no construction, so no significant impacts are apparent. The following sections describe the values observed for each parameter including a comparison to baseline conditions.

2.4.1.1 Gaseous Pollutants

A. Ozone (O_3) Trends of the seasonal average, minimum,and maximum ozone values from February 1975 through December 1983 are shown in Figure 2.4-1. The highest one-hour ozone value observed at the background site (A6/A4) was 163 $\mu g/m^3$ in May 1977. The peak values often occur in the summer, associated with a greater abundance of sunlight for O_3 formation. Generally, the peaks are slightly greater than 50% of the National Ambient Air Quality Standard (NAAQS) of 235 $\mu g/m^3$.

The highest monthly average of 96 $\mu g/m^3$ occurred in February 1979. That month was very cold and stormy with an unusual number of upper-

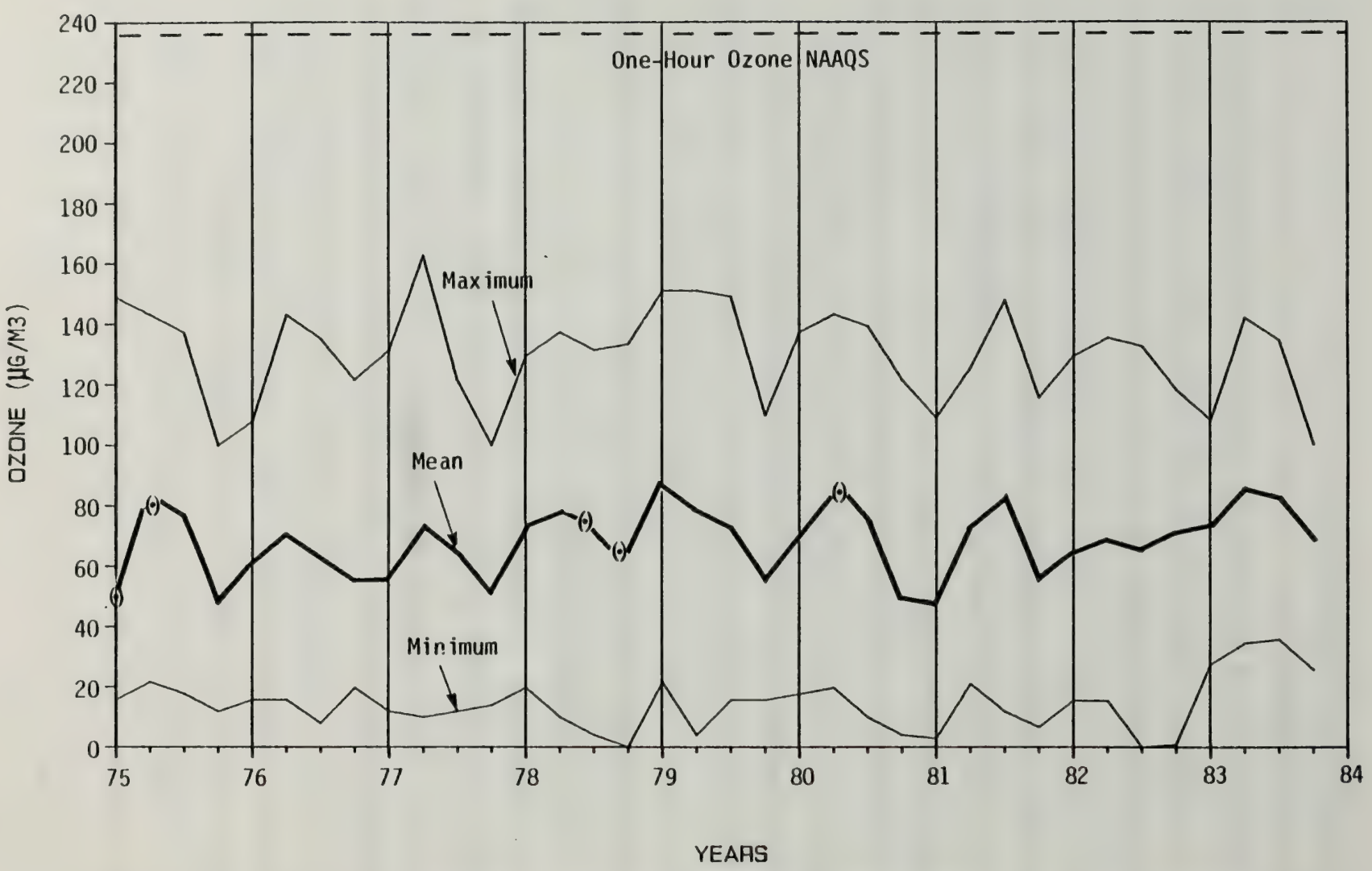


FIGURE 2.4-1. Seasonal minimum, mean, and maximum hourly ozone values from February 1975 through December 1983. (•) indicates data do not meet EPA (1977) averaging criteria.

level ozone intrusions accompanying frontal passages. According to Chan and Smith (1981), the ozone concentrations on the tracts depend a great deal on the ozone content of the troposphere. Year-to-year variability correlates with the passage of fronts over the site. Unusually high one-hour ozone concentrations (>100 $\mu g/m^3$) can be attributed to ozone intrusions accompanying frontal passages, strong atmospheric mixing that brings ozone from aloft to the surface, or long-range transport from urban areas.

Both the peaks and averages show a definite seasonal pattern from year to year, with a fairly constant trend of mean values. Table 2.4-1 shows that the seasonal mean ozone in 1983 was slightly higher than the baseline years, but that all 1983 values were within the range of baseline concentrations. Consistent with the baseline period, the highest 1983 value occurred in the late spring, with the lowest values generally in the fall. The highest and second highest one-hour ozone concentrations in 1983 were 142 and 141 $\mu g/m^3$, respectively, measured in June. The nominal detection limit for the ozone analyzer is 2 $\mu g/m^3$ and the instrument's validity limit is ± 6 $\mu g/m^3$.

The diurnal distribution of hourly ozone concentrations is shown in Figure 2.4-2. Only the months of January and July are shown, but those months should be representative of the variation throughout the year. The daily minimum occurs in the early morning, while the maximum occurs in the afternoon. The difference between the morning and afternoon values is larger in July than January due to increased solar insolation in that season. However, January shows a greater variation in

TABLE 2.4-1. Comparison of seasonal minimum, mean and peak one-hour ozone concentrations ($\mu g/m^3$) between 1983 and baseline (1975-1981).

Season	Baseline (A6)			1983 (A4)		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Winter	3	66	151	27	74	108
Spring	4	74	163	34	85	142
Summer	4	74	149	35	82	134
Fall	4	52	133	25	69	100
Annual		66			77	

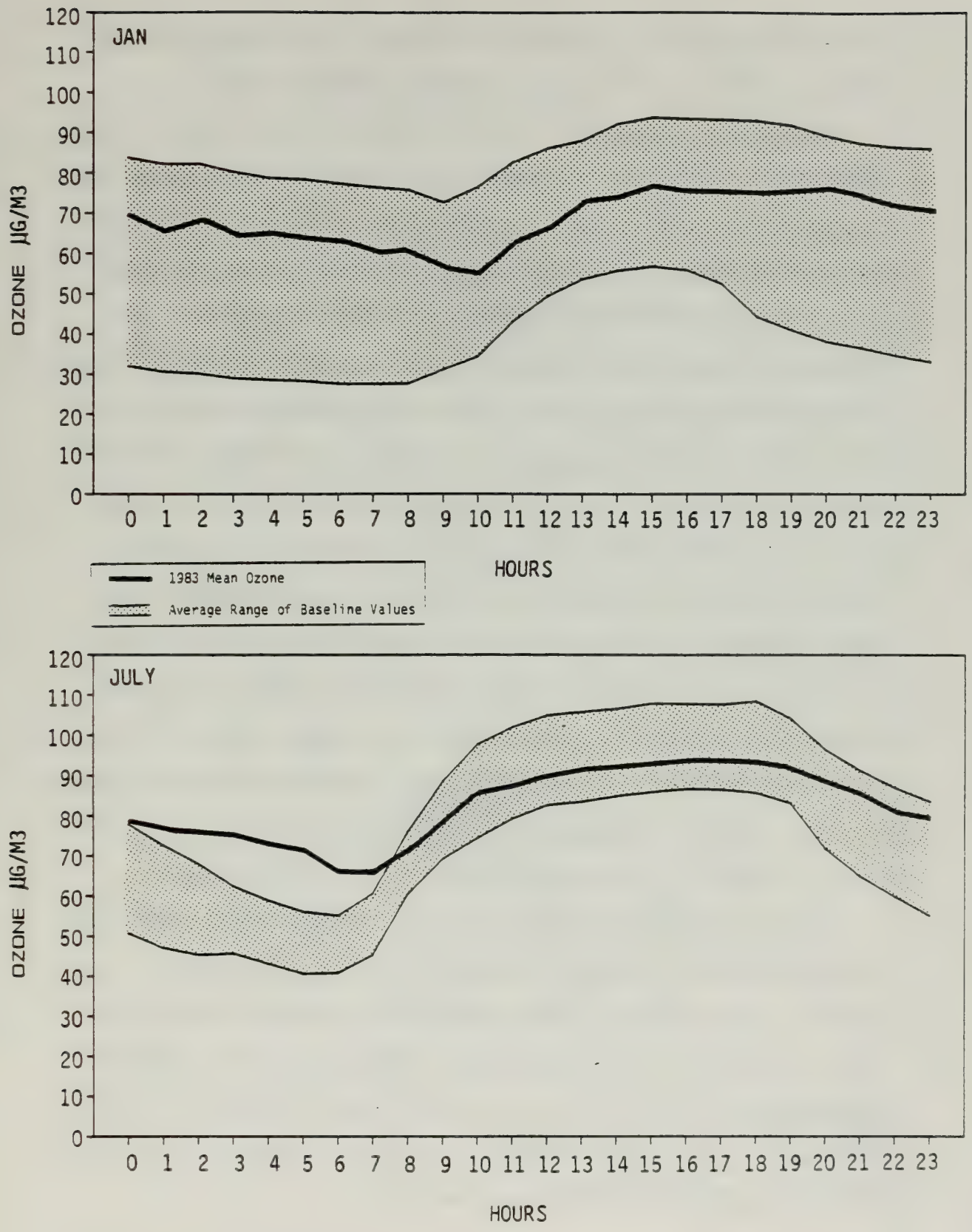


FIGURE 2.4-2. Diurnal distribution of hourly ozone concentrations for January and July 1983.

values during each hour for the baseline range, most likely due to the greater storminess in winter and subsequent ozone intrusion.

The diurnal distribution of hourly ozone values for 1983 at Site A4 predominantly lies within the range of the average minimums and maximums measured during the baseline. The only exception to this is the July early morning case (0000-0700) where the 1983 mean is slightly higher than the average hourly maximums measured during the baseline. The 1983 mean July ozone concentrations during the rest of the day are within the baseline norm, although ozone levels in the evening do not drop off as much as normal. As a result, the difference between the diurnal maximums and minimums is less for July 1983 than for July in previous years. July 1983 had more storms and frontal passages than previous years, which could account for more consistent overall ambient ozone levels throughout the day and night due to upper-level ozone intrusion. The storms would also mean increased cloud cover, reducing afternoon insolation and preventing high daylight hourly ozone values. In fact, the July net radiation data confirm that the mornings and evenings experienced less negative radiation than normal, indicating the presence of more cloud cover and stormy conditions than in the baseline years.

Figure 2.4-3 shows pollution roses for the 1983 annual ozone concentrations at Station A4 and for the baseline period at Station A6. The frequency of occurrence of ozone at both sites is predominantly split between the W, WNW and SE, SSE sectors. These sectors also represent the predominant wind directions for these sites. Therefore, the distribution more likely relates to general background conditions than transport from a source in a particular direction.

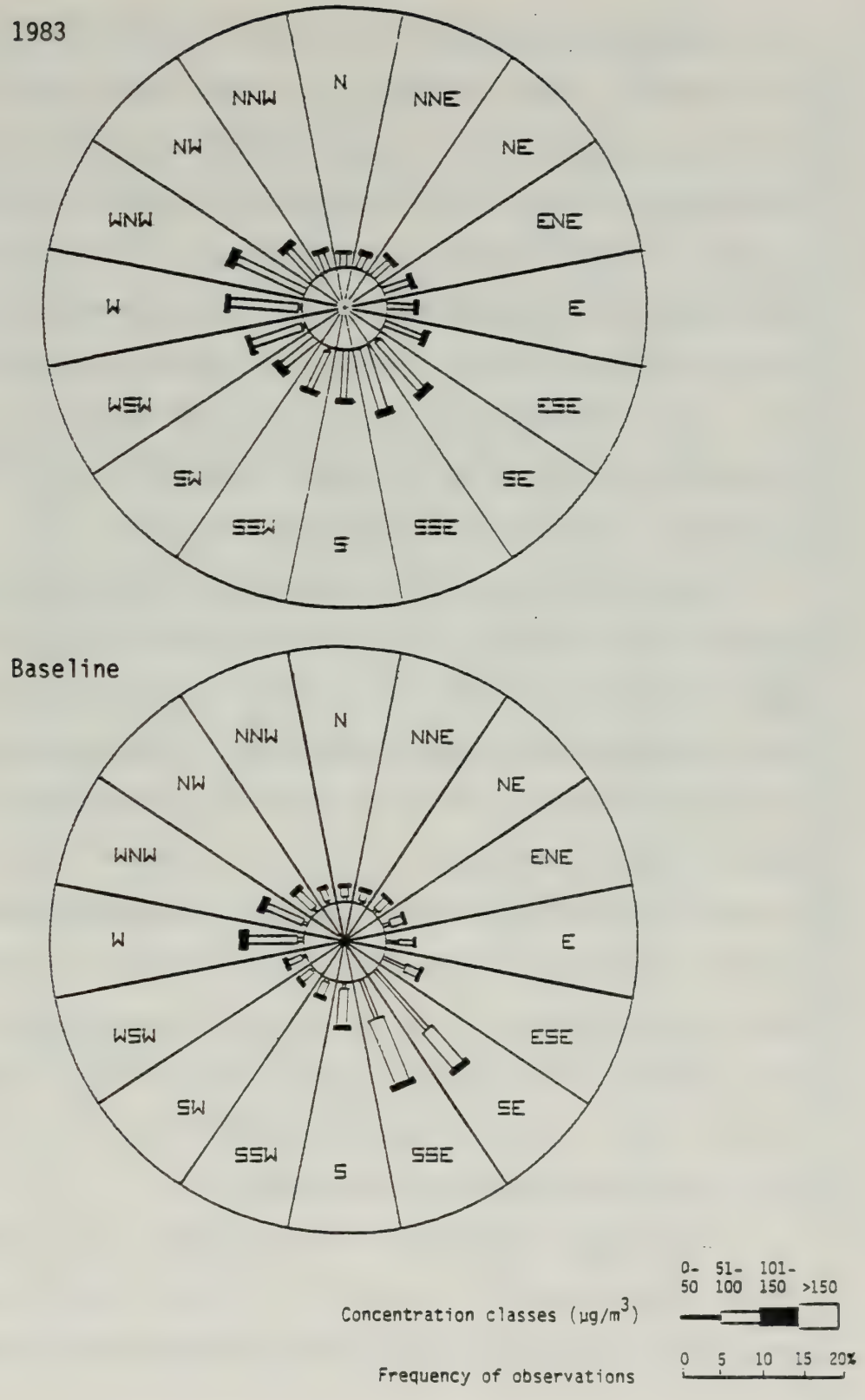


FIGURE 2.4-3. Ozone pollution roses for Site A4 for 1983 and Site A6 for the baseline period, 1975-1981.

B. Carbon Monoxide (CO) The trend of CO values during the monitoring program is shown in Figure 2.4-4. This figure shows that all readings have been very low. The peaks are all less than 10% of the 1-hour NAAQS of 40 mg/m^3, with the maximum of 3.0 mg/m^3 occurring in the summer of 1975. The mean seasonal values are all less than 1.0 mg/m^3. These values are fairly consistent and do not show a strong seasonality at these low concentrations. Similarly, no definite diurnal patterns exist. The slight jump which starts in mid-1980 is actually an artifact of changing the scale on the instrument, rather than a real data change. The detection limit of the instrument is 0.1 mg/m^3.

The seasonal CO means and maximums in 1983 are compared to similar baseline values in Table 2.4-2. All minimum concentrations are at the lower detection limit. Both the 1983 means and peaks are comparable to the values observed during the baseline. The maximum one-hour value of 2.7 mg/m^3 observed in 1983 is much lower than the 40 mg/m^3 NAAQS. Likewise, the peak 1983 eight-hour value of 2.5 mg/m^3 is well below the applicable NAAQS of 10 mg/m^3, although it is somewhat higher than the previous eight-hour maximum of 1.8 mg/m^3 observed in 1976. These high CO values may partially be due to zero drift problems associated with a change of instrument at A4 shortly before these values were observed, but could also be related to the increase in traffic and mining equipment on the tracts for project development.

C. Nitrogen Dioxide (NO_2) Of the nitrogen oxides, only NO_2 has a NAAQS (annual average of 100 $\mu g/m^3$). The trend of NO_2 mean and maximum one-hour averages during the entire monitoring period is shown in

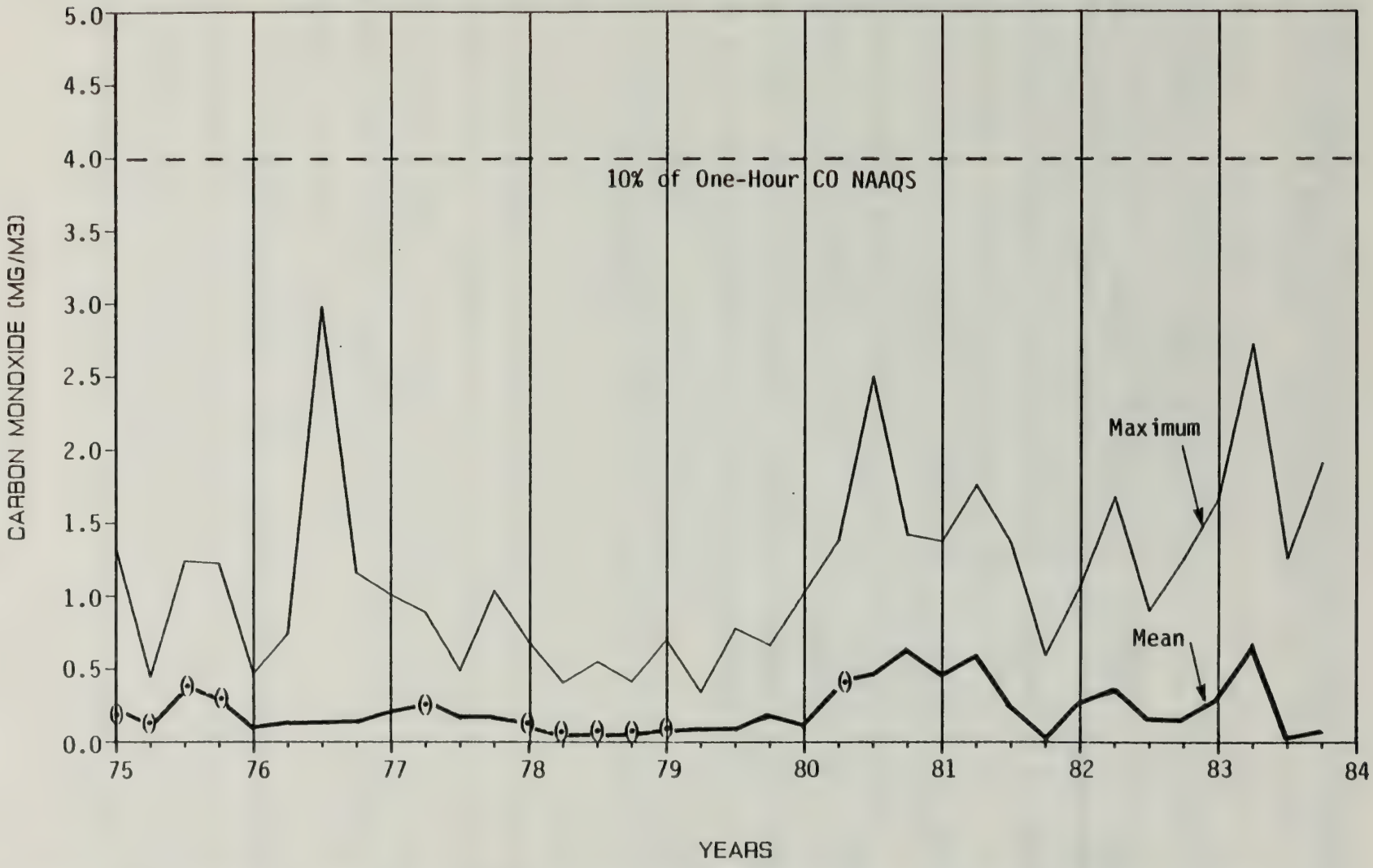


FIGURE 2.4-4. Seasonal trend of hourly maximum and mean carbon monoxide concentrations from February 1975 through December 1983. (•) indicates data do not meet EPA (1977) averaging criteria.

TABLE 2.4-2. Comparison of seasonal mean and peak 1- and 8-hour CO concentrations (mg/m^3) between 1983 and baseline (1975-1981).

Season	Averaging Time	Baseline (A6)		1983 (A4)	
		Mean	Maximum	Mean	Maximum
Winter	1-hour	0.2	1.4	0.3	1.7
	8-hours	-	1.2	-	1.0
Spring	1-hour	0.3	1.8	0.7	2.7
	8-hours	-	1.4	-	2.5
Summer	1-hour	0.2	3.0	0.0	1.3
	8-hours	-	1.8	-	0.9
Fall	1-hour	0.2	1.4	0.1	1.9
	8-hours	-	1.3	-	1.9
Annual		0.2		0.3	

Figure 2.4-5. Most values are very low, with means around the lower detection limit of 5 $\mu g/m^3$. The maximum concentration observed was 100 $\mu g/m^3$ in the summer of 1975. The somewhat higher peaks shown in 1975 and 1976 and again in 1982 and 1983 are most likely associated with the higher levels of activity on tract in those years. Even during these periods, the means are consistently low, and all annual averages have been less than 5% of the 100 $\mu g/m^3$ NAAQS. No season or diurnal patterns appear at these low concentration levels.

Table 2.4-3 shows the 1983 seasonal means and maximums compared to those observed during the baseline period. The maximum one-hour average observed in 1983 was 44 $\mu g/m^3$. As a reference, California has a one-hour standard of 470 $\mu g/m^3$. The maximum 1983 annual NO_2 average of 1 $\mu g/m^3$ was much lower than the 100 $\mu g/m^3$ NAAQS. These values are within the range of values seen during the baseline.

D. Sulfur Dioxide (SO_2) Figure 2.4-6 shows the SO_2 trends of mean and maximum one-hour averages for all the years monitored. Maximum SO_2 levels throughout are extremely low at less than 4% of the 1,300 $\mu g/m^3$ three-hour NAAQS. The highest one-hour level observed was only 45 $\mu g/m^3$ in the spring of 1982, and the means are generally much below the 25 $\mu g/m^3$ instrument lower limit of detection. Similar to CO and NO_2, SO_2 does not show a seasonal or diurnal pattern.

For a numerical comparison, Table 2.4-4 shows the mean and maximum SO_2 levels during the baseline period and in 1983. The 1983 year had a somewhat higher mean than the baseline, but the maximum is less than the peaks observed in the baseline. With respect to the applicable

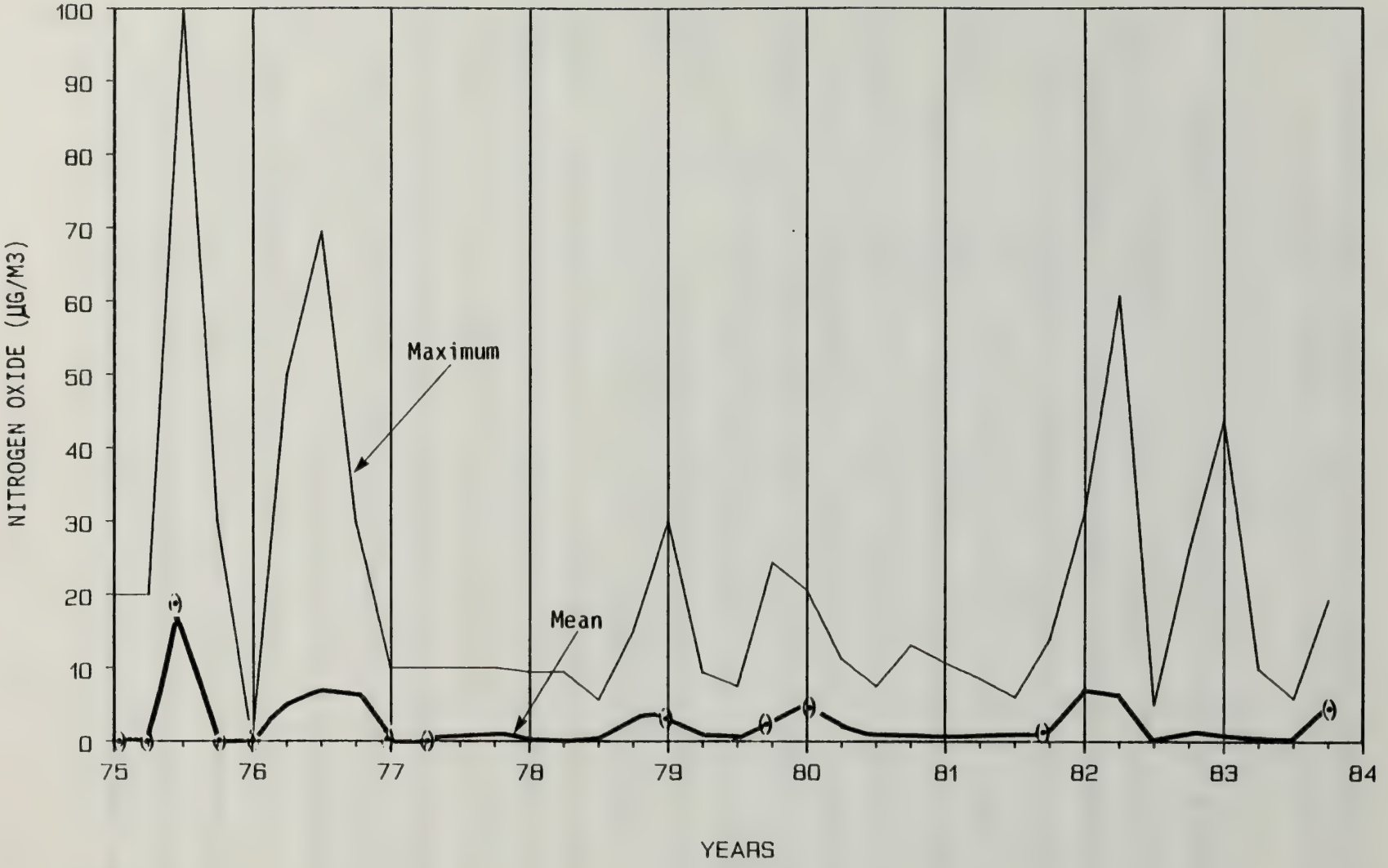


FIGURE 2.4-5. Seasonal trend of hourly NO_2 maximum and mean concentrations from January 1975 through December 1983. (•) indicates data do not meet EPA (1977) averaging criteria. (Note: NO_2 does not have a short-term NAAQS.)

TABLE 2.4-3. Comparison of seasonal mean and peak one-hour NO_2 concentrations ($\mu g/m^3$) between 1983 and baseline (1975-1981).

Season	Baseline (A6)		1983 (A4)	
	Mean	Maximum	Mean	Maximum
Winter	1*	30	1	44
Spring	2	47	<1	10
Summer	2	100	<1	6
Fall	3*	36	6	19
Annual	2		1	

* Less than five seasons.

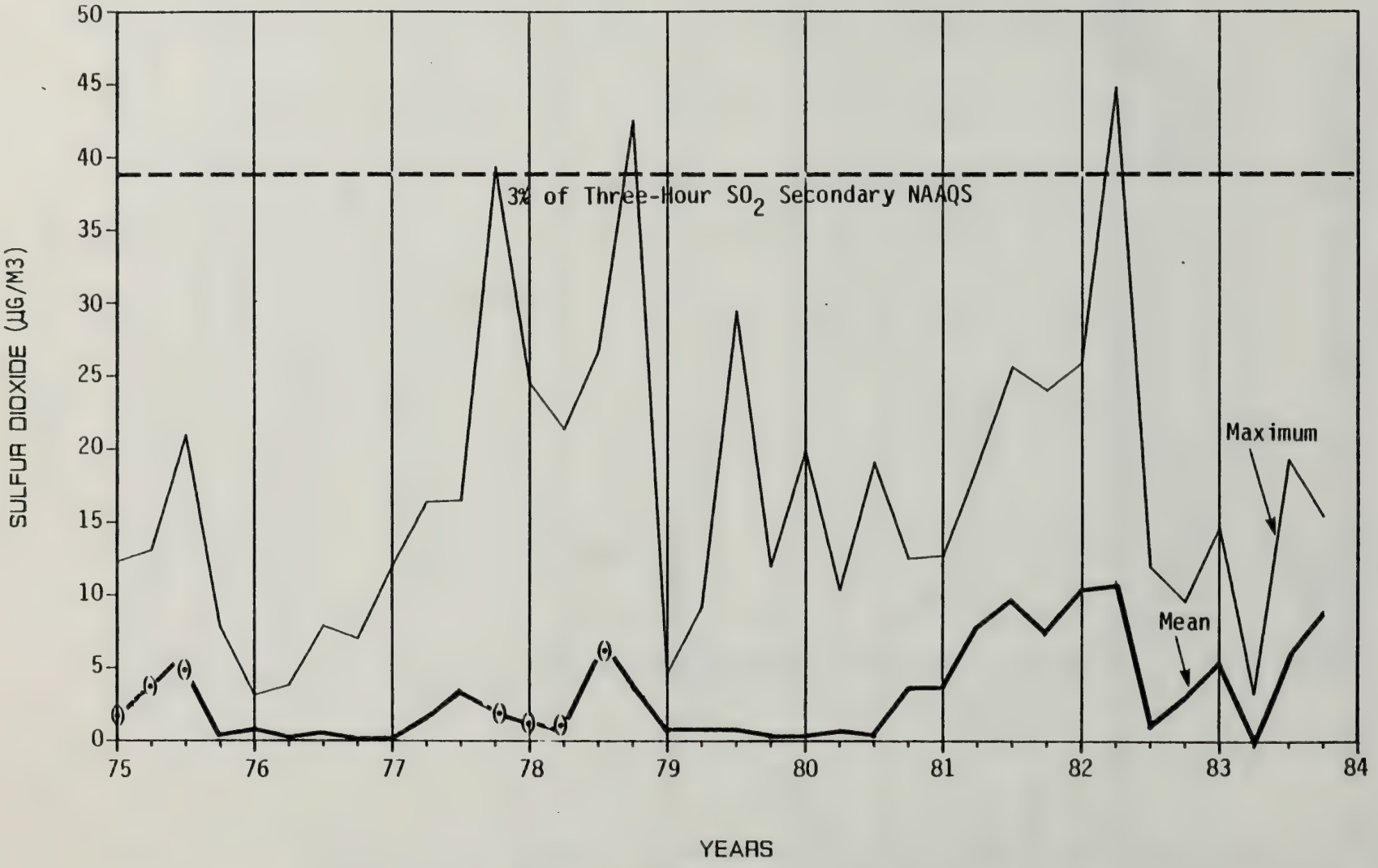


FIGURE 2.4-6. Seasonal trend of hourly SO_2 maximum and mean concentrations from January 1975 to December 1983. (·) indicates data do not meet EPA (1977) averaging criteria.

TABLE 2.4-4. Comparison of seasonal mean and peak three- and 24-hour SO_2 concentrations ($\mu g/m^3$) between 1983 and baseline (1975-1981).

Season	Averaging Time	Baseline (A6)		1983 (A4)	
		Mean	Maximum	Mean	Maximum
Winter	3-hour	1	18	5	15
	24-hour	-	11	-	13
Spring	3-hour	2	16	0	3
	24-hour	-	13	-	1
Summer	3-hour	3	24	6	18
	24-hour	-	16	-	17
Fall	3-hour	3	25	9	15
	24-hour	-	17	-	14
Annual		2		5	

NAAQS, the 1983 peak three-hour average was 18 $\mu g/m^3$ (versus a 1,300-$\mu g/m^3$ standard) and the highest 24-hour average was 17 $\mu g/m^3$ (versus a 365-$\mu g/m^3$ standard). SO_2 also has an annual NAAQS of 80 $\mu g/m^3$, much above the 5 $\mu g/m^3$ average observed in 1983.

2.4.1.2 Particulates Only total suspended particulates (TSP) were monitored in 1983. It is anticipated that inhalable particulate monitoring will be started prior to major surface facility construction activities as planned in the Environmental Monitoring Manual.

High-volume samplers were used to monitor TSP daily at stations A4 and A10 until September 5, 1983, and every third day for the remainder of the year. The sampling schedule was changed based on an analysis done by AeroVironment in July 1983 which showed that no significant difference (99% confidence based on a t-test with $\alpha = 0.01$) existed between annual means computed from a six-day versus a daily sampling schedule. Though the analysis indicated good agreement between daily and six-day sampling schedules, a three-day sampling schedule was requested by the Area Oil Shale Officer as a compromise. This relationship should remain valid as long as impact levels remain near the background concentrations.

Two samplers were operated at station A4, one the "designator" and the other the "collocator." The collocator was only operated every sixth day, timed to coincide with the three-day designator schedule used later in the year. The collocator was used to determine the precision of the TSP data; accuracy is determined through periodic audits. Standard procedures were used to determine precision and accuracy, as

specified in the PSD guidelines Section 6.3.2.1 and 6.3.2.2 (U.S. EPA, 1978), and 44 Federal Register 27477 (May 1979).

Table 2.4-5 shows the computed precision and accuracy of the TSP samples during days when both the designator and collocator were operating simultaneously. The wide range of the 95% confidence limits is attributed to the low concentrations recorded. For example, a difference of 1 $\mu g/m^3$ at values less than 20 $\mu g/m^3$ is significant, whereas at higher values, the difference would not be as significant. The U.S. EPA PSD guidelines require accuracy to be within $\pm$15%; Table 2.4-5 shows that the accuracy for the designator and collocator samples for 1983 was well within this range (the maximum percent difference of -5.15% was found during the July 13, 1983 audit).

The seasonal minimum, mean, and maximum TSP trends for all years at the background site are shown in Figure 2.4-7. TSP has a natural elevated background, particularly in arid climatic conditions where, due to low soil surface moisture and sparse ground cover, the wind can cause soil erosion. The general dustiness of the tracts is reflected in the graph, which shows means around 40% of the annual secondary NAAQS (60 $\mu g/m^3$), and maximums up to 85% of the 24-hour secondary NAAQS (150 $\mu g/m^3$).

A definite seasonal pattern can be seen in this figure. The means show that generally high TSP values occur in late-spring and summer when winds are highest and precipitation the least. However, the yearly maximums show more irregularity, with dust events occurring from spring through fall, depending on the wind, moisture and tract activity. For example, the peak value of 127 $\mu g/m^3$ occurred in the fall of 1980. The lowest maximums have always occurred in the winter.

TABLE 2.4-5. Precision and accuracy of the TSP samplers at Site A4 during 1983.

Site	Reporting Period	Precision				Accuracy	
		No. of Collected Samples	No. of Samples $\leq 20\ \mu g/m^3$	Confidence Limit		Audit Date	Percent Difference (Di)*
				Lower 95%	Upper 95%		
A4	January-March	13	13	-23.595	23.770	1/19/83	0.00
A4	April-June	14	10	-12.273	20.387	4/7/83	0.22
A4	July-September	14	8	-23.510	36.283	7/13/83	-5.15
A4	October-December	13	12	-7.058	14.266	10/05/83	-1.66

$$*Di = \frac{Yi-Xi}{Xi} \ 100$$

-- known flow rate (m^3/min) = Yi

-- audit flow rate (m^3/min) = Xi

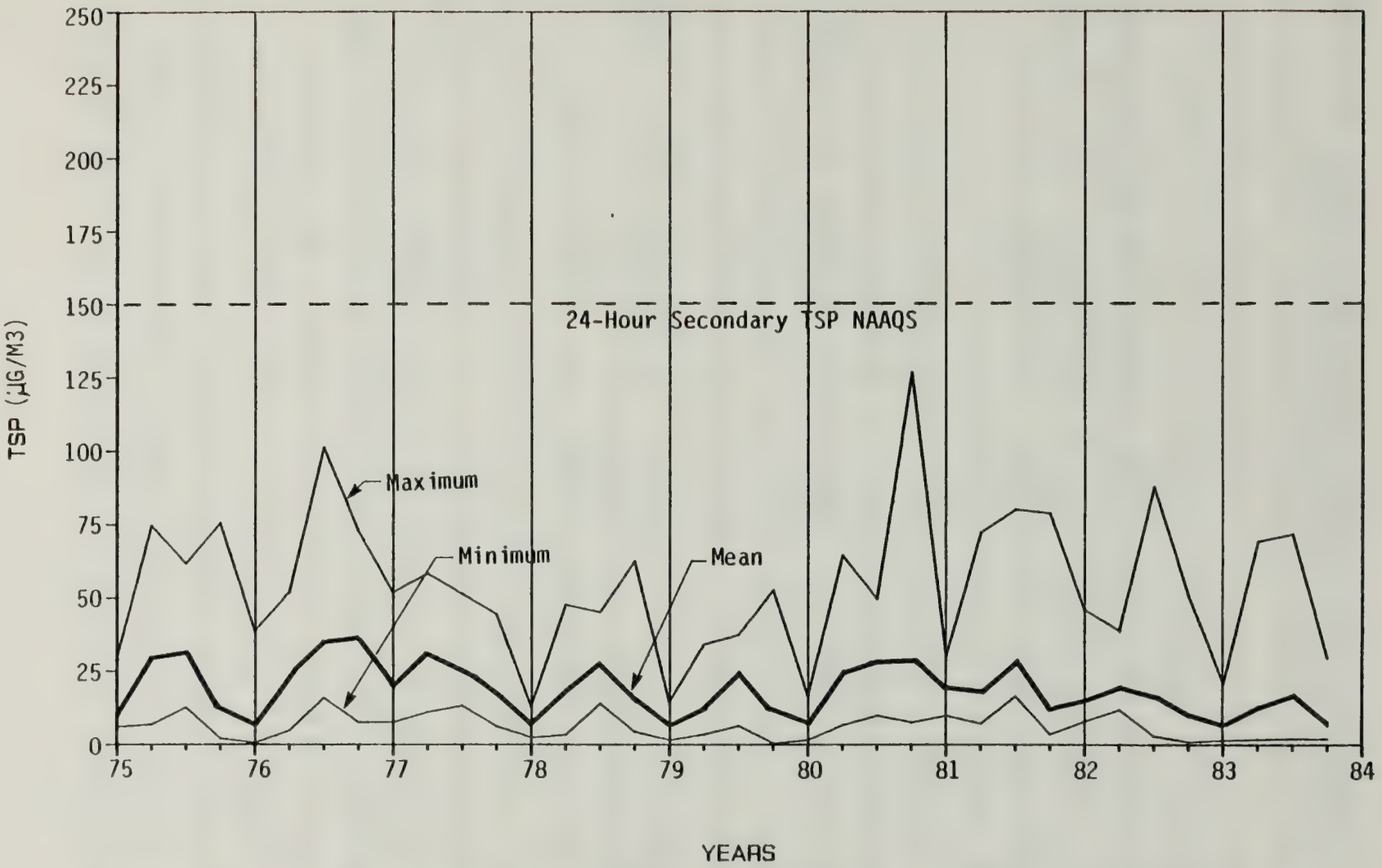


FIGURE 2.4-7. Seasonal minimum, geometric mean and maximum 24-hour TSP trends from January 1975 through December 1983 at the background site.

Table 2.4-6 compares the 1983 geometric mean, minimum, and maximum values from A4 and A10 to the baseline values at A6. Both the background station (A4) and impact station (A10) show comparable values with the baseline. The maximum 24-hour values at the two sites in 1983 were 71.9 $\mu g/m^3$ (A4) and 74.7 $\mu g/m^3$ (A10), both just under half the standard. Both maximums occurred on the same day (September 19), showing the dust was well distributed over the tracts. Wind speeds were high on that day, reaching over 30 mph from the west at A4.

Only 10% of the sampling days in 1983 (266 total) had concentrations over 30 $\mu g/m^3$, and of these, only three days showed more than 20% difference between the concentrations at A4 and A10. This uniformity of TSP levels at both stations, combined with generally below-baseline-level concentrations, implies that there are no appreciable impacts at the monitoring locations attributable to the construction activities (which are mostly dust generating) in 1983.

The annual and seasonal geometric means at both sites were also very similar and somewhat lower than baseline. The geometric mean given can be considered to correspond to the concentration expected 50% of the time because particulate concentrations are generally lognormally distributed. The geometric mean particulate concentration during 1983 ranged from 6.5 $\mu g/m^3$ during the winter months to 18.4 $\mu g/m^3$ during the summer. The annual geometric mean values of 10.7 $\mu g/m^3$ (A4) and 11.2 $\mu g/m^3$ (A10) are well below the 60 $\mu g/m^3$ annual secondary TSP NAAQS.

2.4.1.3 Air Quality Data Summary To summarize the air quality data discussed in the preceding sections, Table 2.4-7 shows the annual

TABLE 2.4-6. Comparison of seasonal geometric means, standard geometric deviations, maximum and minimum 24-hour particulate concentrations ($\mu g/m^3$) between 1983 and baseline (1975-1981).

	Season	Baseline (A6)	1983 (A4)	1983 (A10)
Geometric Mean	Winter	9.9	6.5	7.0
	Spring	21.8	13.0	14.0
	Summer	28.2	16.8	18.4
	Fall	17.7	7.1	7.3
	Annual	18.2	10.7	11.2
Standard Geometric Deviations	Winter	2.2	1.8	1.8
	Spring	2.0	1.9	1.8
	Summer	1.6	1.7	1.7
	Fall	2.6	1.9	3.2
	Annual	2.3	2.0	2.2
Maximum 24-hour Average	Winter	51.9	21.1	21.0
	Spring	74.7	69.4	67.0
	Summer	101.2	71.9	74.7
	Fall	127.0	29.7	52.8
Minimum 24-hour Average	Winter	0.7	1.6	1.5
	Spring	3.3	1.9	2.9
	Summer	6.5	2.1	1.9
	Fall	0.5	2.0	0.1

TABLE 2.4-7. Annual average (gaseous) and annual geometric mean (particulates) pollutant concentrations for the entire monitoring period.

Year	Site	Pollutant				
		O_3 $\mu g/m^3$	CO mg/m^3	NO_2 $\mu g/m^3$	SO_2 $\mu g/m^3$	TSP $\mu g/m^3$
75	A6 ↓	67	(0.2)	(5)	(3)	19.5
76		62	0.1	5	<1	20.4
77		61	0.2	1	2	22.6
78		74	(0.1)	1	3	15.0
79		73	0.1	(1)	1	12.5
80		68	0.4	2	1	19.6
81		65	0.3	1	7	18.5
82		67	0.2	4	6	14.4
83	A4 ↓	77	0.3	1	5	10.3

( )Averages based on data of insufficient quantity to meet EPA (1977) criteria.

averages (geometric means for TSP) for all the pollutants for all the monitored years. As discussed, O_3 and TSP show a consistent non-zero background, and the others, CO, NO_2 and SO_2, are all around the lower limit of detection for those instruments. These annual averages are plotted in Figure 2.4-8 to see if there was any simultaneous trend among the various pollutants; no consistencies are apparent.

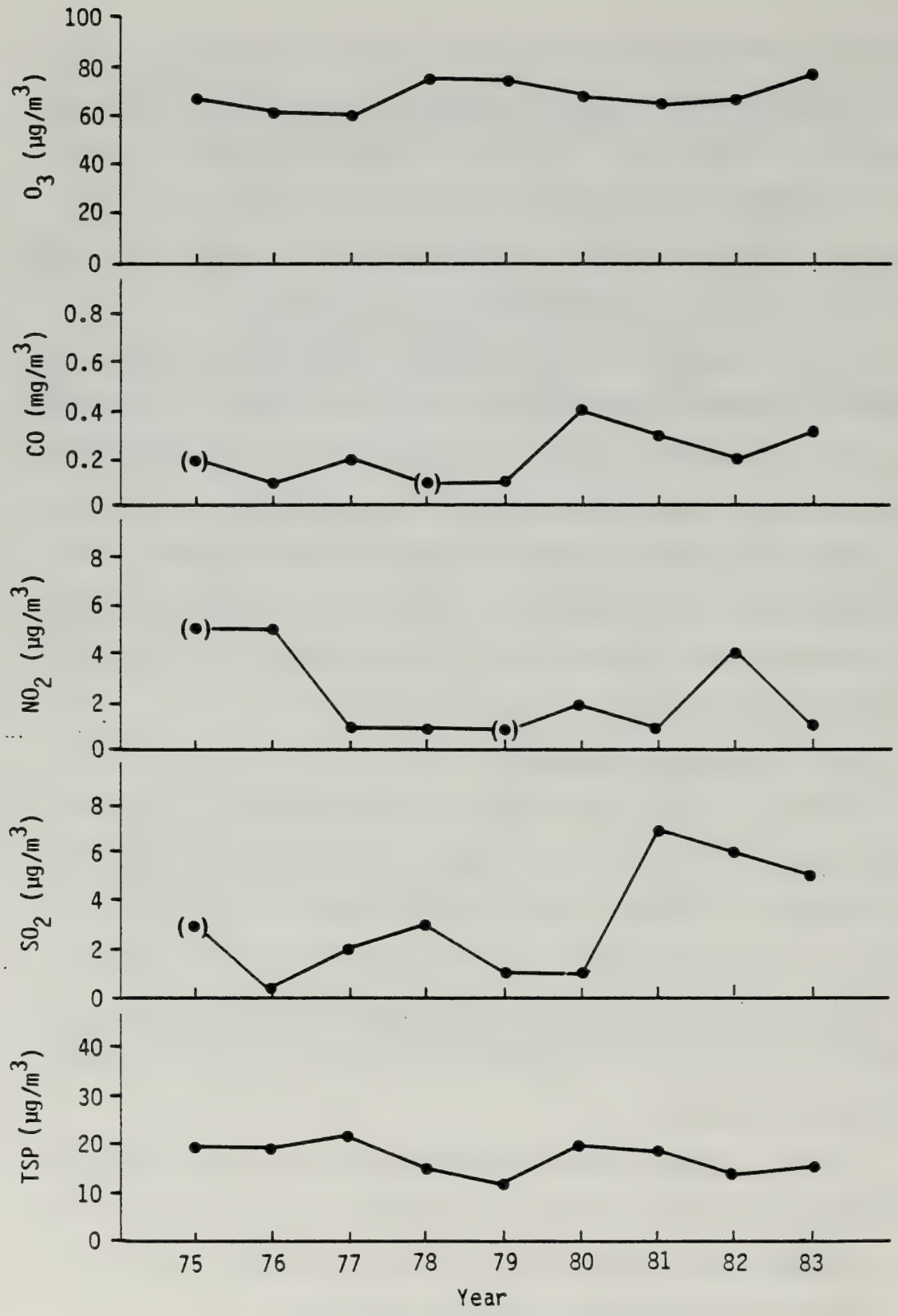
All of the maximum short-term averages corresponding to NAAQS are tabulated in Table 2.4-8. Again, no real pattern appears from year to year except that the values of any one pollutant are fairly constant. The data criteria used to compute these averages is given in Table 2.4-9.

None of the values in these tables exceed any of the NAAQS. For easy reference, the maximum concentrations observed in 1983 are compared to these standards in Table 2.4-10. Ozone and TSP approach 60% of their respective standards, with all others very low.

2.4.2 Atmospheric Processes

In order to predict what future air quality impacts are likely from a large-scale oil shale development, a thorough understanding of the atmospheric conditions into which emissions will be released is vital. Previous measurements have included both special experiments and routine long-term monitoring. These routine measurements were continued in 1983 and will be discussed and compared to the baseline in the following sections.

2.4.2.1 Climate Before discussing the details of the transport and dispersion characteristics of the atmosphere over the Ua-Ub tracts, it is appropriate to summarize the major weather systems that affect the large-scale movement of air masses over the area.



(•) Averages based on data of insufficient quantity to meet EPA (1977) criteria.

FIGURE 2.4-8. Trends of annual averages of all pollutants during the monitoring program at the background station.

TABLE 2.4-8. Maximum observed concentrations ($\mu g/m^3$) corresponding to relevant short-term averaging times for the entire monitoring period.

Year	Site	Pollutants						
		O_3	CO (mg/m^3)		NO_2	SO_2		TSP
		(1-hr)	(1-hr)	(8-hr)	(1-hr)	(3-hr)	(24-hr)	(24-hr)
75	A6	149	1.3	1.0	100	21	13	75.6
76		143	3.0	1.8	70	6	4	101.2
77		163	1.0	0.9	13	16	10	58.3
78		137	0.7	0.4	15	25	15	62.7
79		151	0.8	0.7	30	19	4	52.9
80		143	2.5	1.5	21	17	9	127.0
81		148	1.8	1.3	14	24	19	80.4
82		135	1.7	1.2	61	37	23	75.9
83	A4	142	2.7	2.5	44	18	17	71.9

TABLE 2.4-9. Averaging criteria, U.S. EPA, 1977.

Time Interval	Minimum Number of Observations
3-hour running average	3 consecutive hourly observations
8-hour running average	6 hourly observations
24-hour	18 hourly observations
Monthly	21 daily averages
Quarterly	3 consecutive monthly averages
Yearly	9 monthly averages with at least two monthly averages per quarter

TABLE 2.4-10. Comparison between national and Utah air quality standards for air pollutants with maximum levels observed for the Ua/Ub tracts in 1983.

Pollutant	Averaging Time	Primary Standards	Secondary Standards	Maximum 1983 Concentrations
Ozone (O_3)	1-hour	235 $\mu g/m^3$ (0.12 ppm)	Same as primary	142 $\mu g/m^3$
Carbon monoxide (CO)	8-hour	10 mg/m^3 (9 ppm)	Same as primary	2.5 mg/m^3
	1-hour	40 mg/m^3 (35 ppm)	Same as primary	2.7 mg/m^3
Sulfur dioxide (SO_2)	annual average	80 $\mu g/m^3$ (0.03 ppm)	-	5 $\mu g/m^3$
	24-hour	365 $\mu g/m^3$ (0.14 ppm)	-	17 $\mu g/m^3$
	3-hour	-	1,300 $\mu g/m^3$ (0.5 ppm)	18 $\mu g/m^3$
Nitrogen dioxide (NO_2)	annual average	100 $\mu g/m^3$ (0.05 ppm)	Same as primary	1 $\mu g/m^3$
Total suspended particulates (TSP)	annual geometric mean	75 $\mu g/m^3$	60 $\mu g/m^3$	11.2 $\mu g/m^3$
	24-hour	260 $\mu g/m^3$	150 $\mu g/m^3$	74.7 $\mu g/m^3$

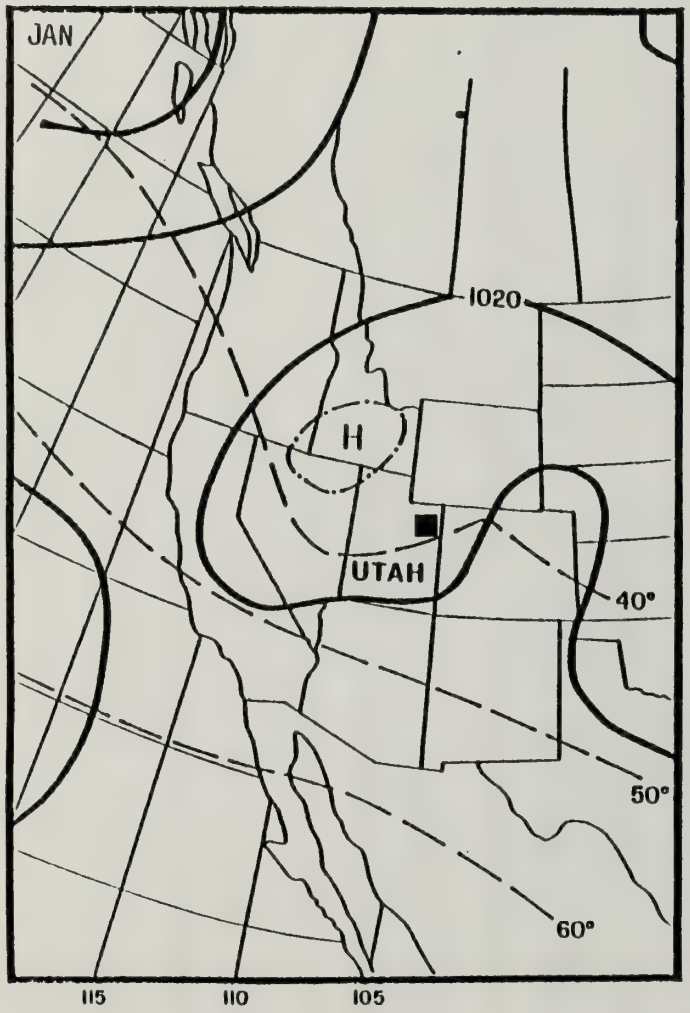
The horizontal transport of an air mass is a consequence of large-scale differences in air pressure. The factor determining Utah's weather during the winter months is the location and strength of the Intermountain Region High Pressure Cell. Figure 2.4-9a shows the normal January sea-level pressure and temperature. Storm tracks during mid-winter tend to pass north through Montana and through southern Utah. After February, storm tracks are more prevalent over northern Utah as the strength of the Basin High wanes. Precipitation is highest during the spring months.

During the summer months (Figure 2.4-9b), the pressure is lower, and sporadic moisture from the Gulf of Mexico brings periods of scattered thundershowers. Beginning in September, the storm fronts from the north increase in probability but are interspersed with many periods of clear weather when high pressure builds up in the Intermountain Basin.

Overall, 1983 was a year of anomalous weather, being influenced by El Nino, an event that affected weather on a global scale.

To begin the year, the usual winter ridging over the western United States was less pronounced than normal, allowing a significant number of weather disturbances to pass through the intermountain region. Temperatures were well above normal from January through March, with near normal precipitation in January and February.

Spring was cool and stormy with above normal precipitation from March through May, resulting in a deep snowpack in the mountains. Temperatures in April and May were well below normal.



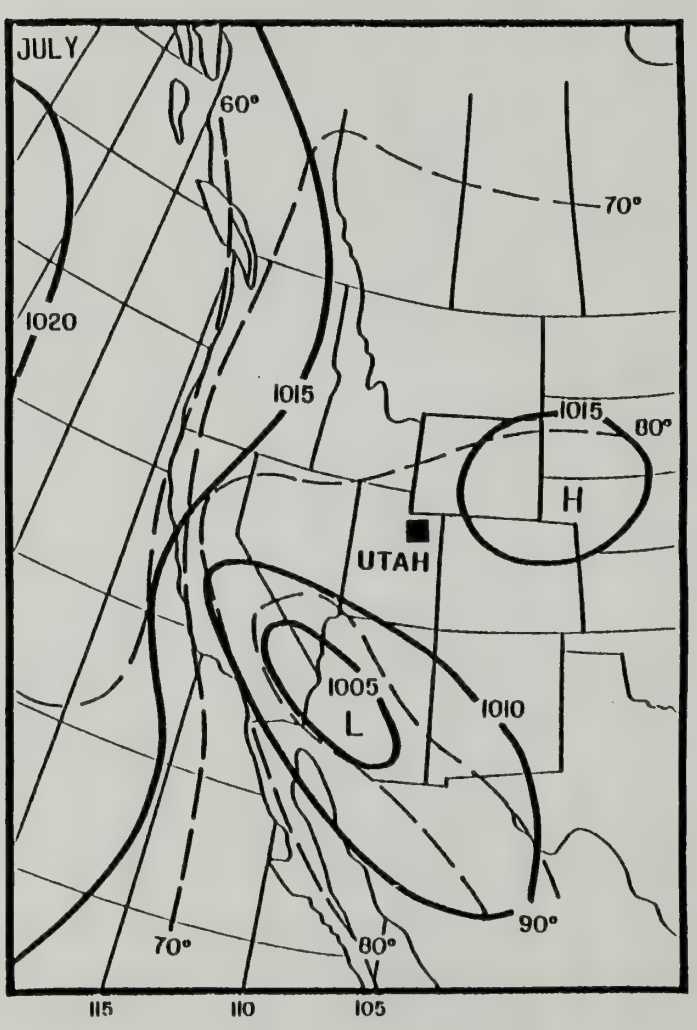


FIGURE 2.4-9. Normal sea level pressure in mb (solid lines) and temperature in ^{o}F (dashed lines).

Source: National Weather Bureau, 1952.

Towards the end of May, a ridge of high pressure was established over the northern intermountain region, resulting in a heat wave that extended into June. This heat wave and near-normal June rainfall caused snowmelt flooding in the Utah valleys. July was colder than normal with above normal precipitation.

In August and September, the intermountain region was affected by a northward intrusion of tropical moisture that caused showers and consequent mudslides. Temperatures were generally warmer than normal. In contrast, October was dry with near normal temperatures.

November and December proved to be extremely stormy, with wave after wave of disturbance tracking across the region. Abnormally large accumulations of snow resulted in the mountains and valleys.

2.4.2.2 Meteorology 1983 meteorological data are summarized below and compared to baseline data (1975-1981) to identify significant deviations.

A. Surface Wind Flow Table 2.4-11 lists monthly average and peak wind speed and prevailing direction for the five monitoring stations during 1983. These data are similar to wind observations made in previous years, as shown in Figure 2.4-10. This figure shows the seasonal mean and peak wind speed (10 m) for the monitoring period at A6. The mean wind shows a definite seasonal pattern, with generally the highest winds in spring and summer and lowest in fall and winter. The peaks show more irregularities, with some peaks in fall and winter likely associated with storms. However, spring peaks are the most prevalent.

TABLE 2.4-11. Monthly average and peak wind speeds (mph) and prevailing directions for 1983.

1983 Month	Site A4			Site A6			Site A10			Site A11			Site A13		
	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.	Avg. W.S.	Peak W.S.	W.D.
JAN	3.9	27.1	W	2.3	23.9	SE	2.4*	6.9	NNW*	4.0	30.3	WNW	1.5*	4.7	SE*
FEB	4.6	14.0	W	3.3	12.7	SSE	2.5	14.1	N	4.5	15.1	WNW	--	--	SE
MAR	6.2	23.9	SE	5.3	20.0	SSE	4.3	26.3	NE	6.2	23.5	SE	4.0*	13.6	SE*
APR	6.3	21.9	SE	6.2	24.9	SSE	4.0	26.1	NE	7.0	27.5	SE	5.6*	23.0	S*
MAY	6.4	28.6	WNW	6.6	29.0	SSE	4.7	27.6	ENE	7.7	25.1	SE	6.0	20.7	WNW
JUN	6.6	22.4	SE	6.1	22.5	SSE	4.6	20.4	NE	7.5	25.5	SE	5.9	16.3	SSE
JUL	6.7	21.6	SSE	6.6	23.8	SSE	5.0	20.1	NNE	8.1	29.7	SE	6.1	22.3	SSE
AUG	5.7	19.7	SSE	5.7	24.9	SSE	3.2	27.6	NNE	6.8	27.2	SE	5.1	23.8	SSE
SEP	6.5	30.7	WNW	6.2	28.3	SSE	3.8	16.9	NE	7.8	38.2	SE	5.6	26.6	SSE
OCT	4.7	15.8	SSE	4.3	17.1	SE	2.3	15.0	NE	6.0	17.7	SE	3.8	16.2	SSE
NOV	3.6	26.1	W	4.2	23.1	SSE	2.7	23.5	NNE	5.0	21.7	ESE	3.3	21.1	SSE
DEC	2.9	26.0	W	3.8	24.3	WNW	2.4	21.7	WNW	4.4	23.5	WNW	2.7	21.1	WNW
Annual	5.3	30.7	SE	5.1	29.0	SSE	3.5	27.6	NE	6.3	38.2	SE	4.8**	26.6	SSE

-- No data recovered.
*Low data recovery (less than 60% for month).
**Based on eight (8) months of complete data.

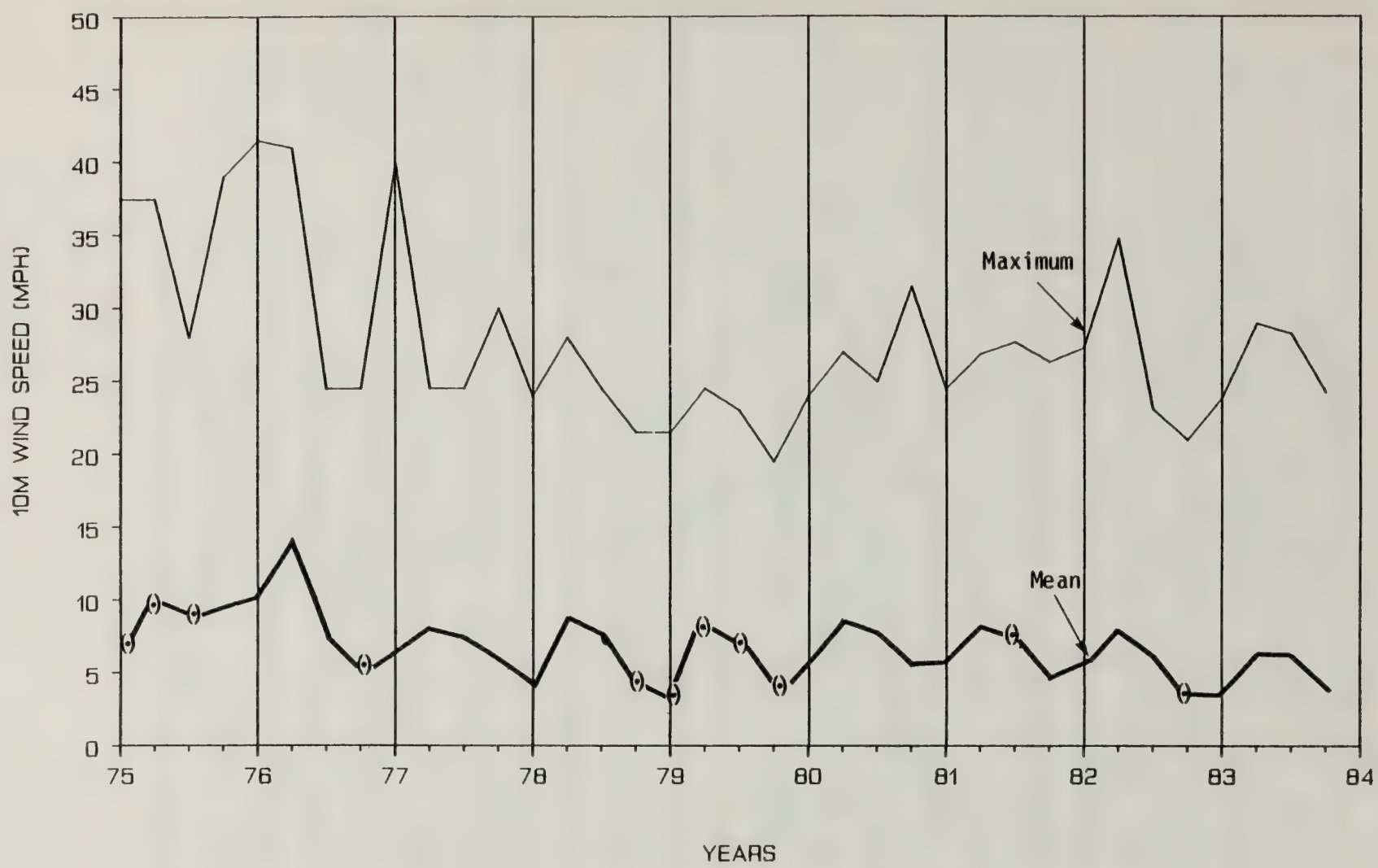


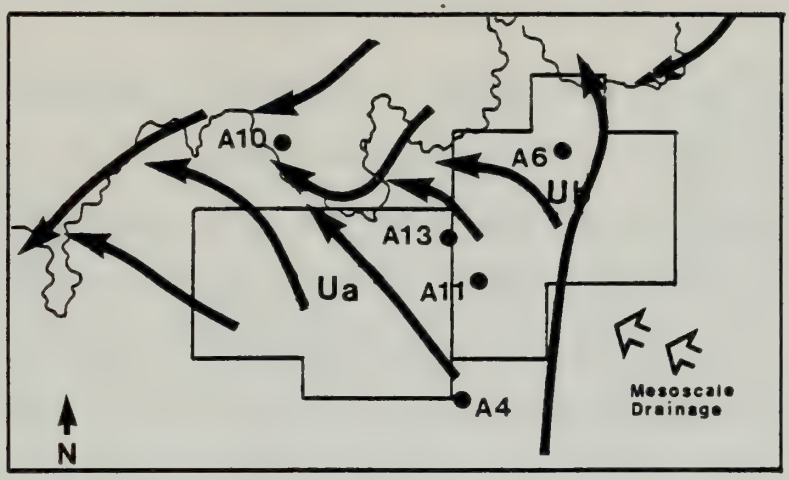
FIGURE 2.4-10. Seasonal mean and peak hourly wind speed (10 m) trends for the monitoring period at A6. (·) indicates data do not meet EPA (1977) averaging criteria.

Three general surface wind flow patterns have been identified from this program: a nighttime drainage flow, a transitional upslope flow and midday westerly flow. The drainage and upslope flow are influenced by topography, whereas the midday flow is induced by synoptic conditions.

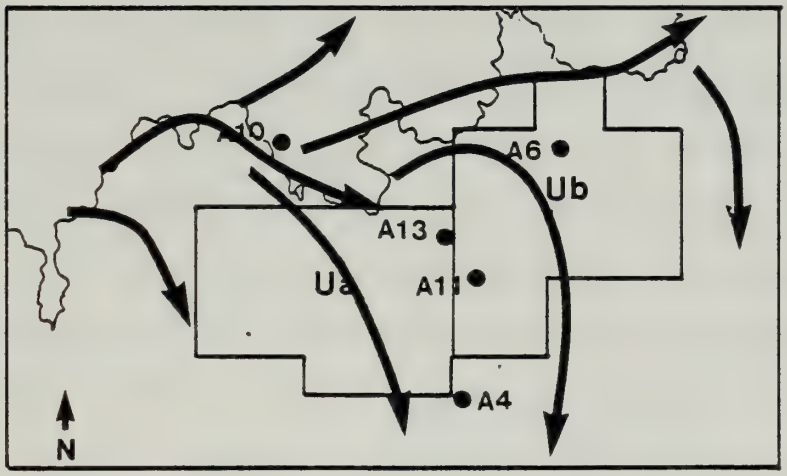
Figure 2.4-11a plots streamlines for drainage flow. The arrows on the figure are general flow streamlines representing early morning hour conditions with mesoscale drainage flow. The drainage flow occurs most often of the three flows, usually from late afternoon through early morning during periods of fair weather. Air flows from higher to lower terrain, down gullies and creek beds. The resulting flow is SE at A4, SSE at A6, NE at A10, SE at A11, and SSE at A13. The dominance of this flow is reflected in the annual prevailing wind directions.

Figure 2.4-11b plots an upslope wind flow that occurs between drainage and synoptic flow periods. Since this pattern is transitional, it generally lasts less than an hour. It is an important factor in pollutant dispersion since plume fumigation would occur under this condition. The surface-based inversion that results from strong radiative cooling begins to lose some of its strength shortly after sunrise. As the morning progresses, the heat gained on the surface from solar radiation exceeds that lost by terrestrial radiation and the soil temperature rises, warming the air above. This creates a pressure difference resulting in upslope flow. Because of its brevity, this pattern is lost in the hourly-average wind direction data. This pattern begins earlier during the summer months than during the winter when the sun rises later.

a. Drainage flow during early morning hours



b. Transitional Flow



c. Afternoon synoptic flow

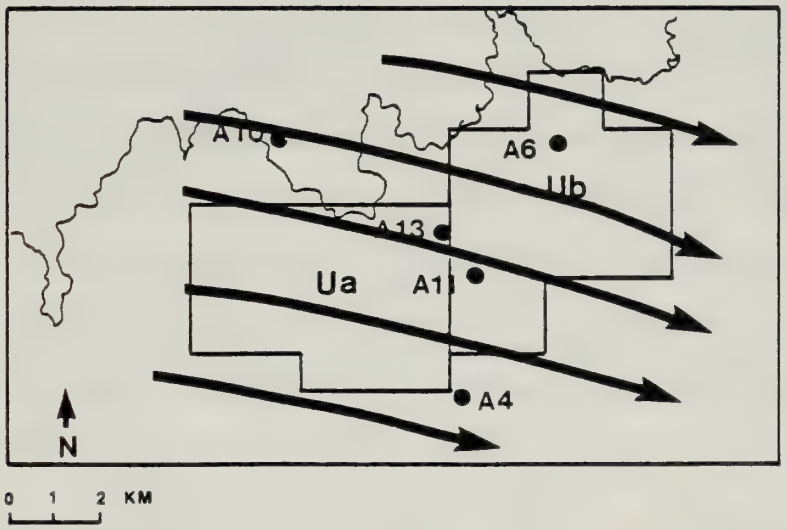


FIGURE 2.4-11. Typical flow pattern on Tracts Ua and Ub during 1975-1983.

During midday and periods of instability or unsettled weather, synoptic-induced flows dominate. Figure 2.4-11c plots streamlines for the afternoon synoptically-induced flow, which produce W to WNW winds over the entire tract. These afternoon flows are generally stronger during the warm months. The most exposed sites, such as A4 and A11, tend to be more influenced by synoptically-induced flow than less exposed sites, such as A10. This explains why A4 and A11 will record a prevailing westerly direction while other sites still record prevailing wind direction resulting from drainage flows during the same period. Because these sites are well exposed, A4 and A11 also recorded the highest average wind speeds. During especially stormy periods such as December 1983, all stations on the tract recorded prevailing W to WNW wind directions because of the dominance of synoptic flow.

Figure 2.4-12 is a plot of A6 monthly averaged hourly wind speed data for January and July 1983. The span of lowest to highest monthly averaged diurnal hourly values during baseline is plotted on the same graph for these months. January 1983 means were only slightly below the average baseline minimum, as were the July means for part of the diurnal cycle. July did not have the normal pronounced afternoon wind flow, probably because July was stormier than normal, with many frontal passages. This influence results in a flatter diurnal pattern. The baseline afternoon peak wind flow is more typical of fair weather periods. The differences between the January and July plots show the greater influence of slow drainage winds in the winter, when the morning versus afternoon wind speeds show less variation, but the presence of winter storms shows more variation in each of the individual hours.

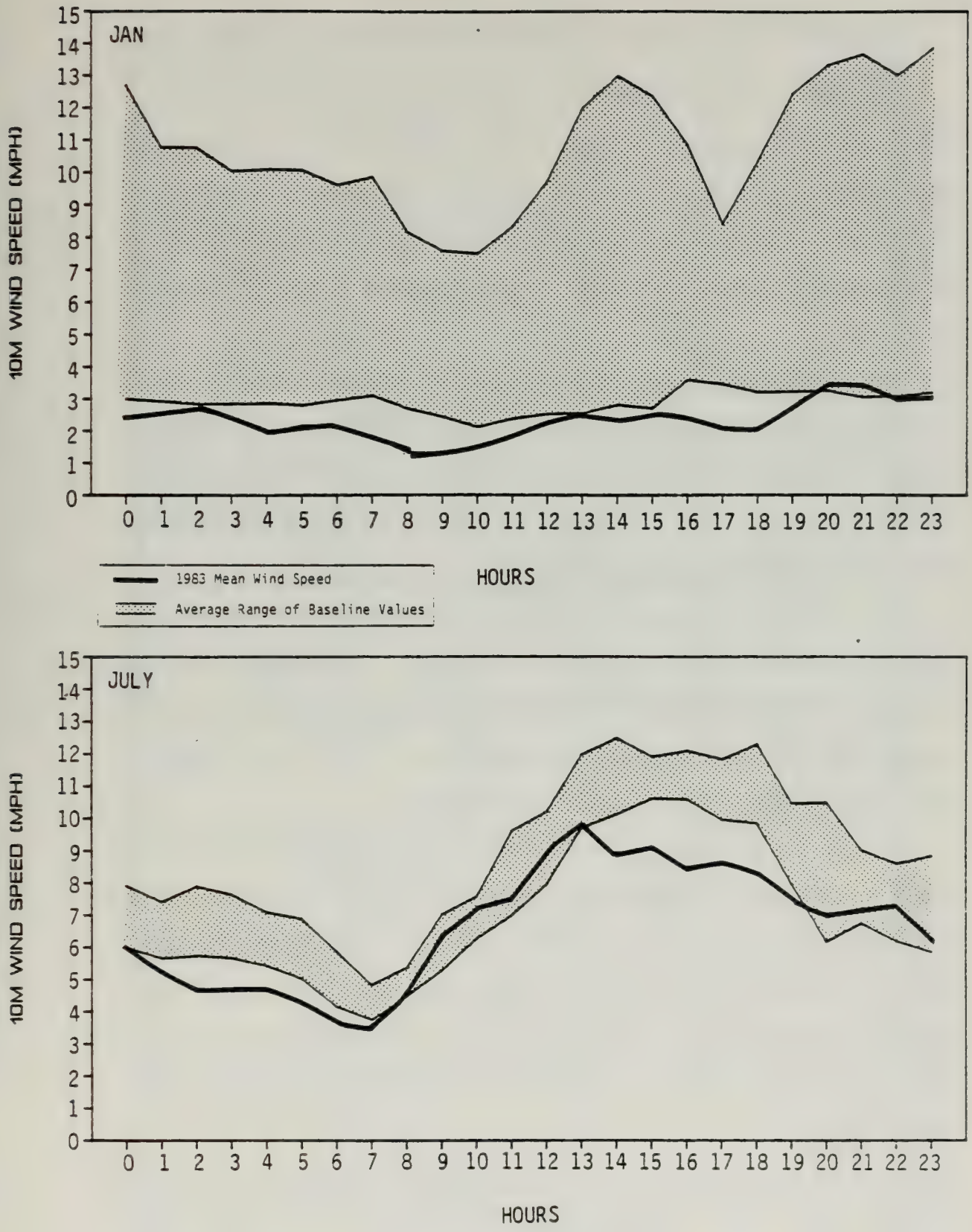


FIGURE 2.4-12. Monthly averaged hourly wind speed (10 m) for January and July 1983 versus baseline for Site A6.

Figures 2.4-13 through 2.4-16 are seasonal wind rose plots for the five wind monitoring stations. The length of each bar represents the frequency of winds from the directions toward which the bar points. These plots illustrate the dominance of drainage and synoptic flows at each of the sites. Only very minor differences exist from season to season.

B. Temperature Figure 2.4-17 plots seasonal mean, maximum and minimum temperatures for 1975 through 1983 at A6. There are no significant differences between 1983 and baseline data. During the program, the highest temperature observed at A6 was 36°C in August 1983 and the lowest was -30°C in January 1979.

Table 2.4-12 lists monthly mean, maximum and minimum temperature for the five meteorological monitoring stations. During 1983, the highest temperature observed was 40.0°C at A13 during August, and the lowest temperature was -23.7°C at A13 during December. Annual mean temperatures ranged from 7.2°C at A11 to 9.0°C at A4.

Figure 2.4-18 compares January and July 1983 mean hourly temperatures to the baseline temperature range for Site A6. January was within the baseline range of values; however, due to abnormally stormy weather with reduced midday solar heating, July midday temperatures were lower than the baseline range. In general, the maximum temperatures are observed between 1400 and 1600 MST, and the minimum temperatures, between 0400 and 0800 MST.

C. Relative Humidity Figure 2.4-19 plots seasonal relative humidity for 1975 to 1983. The mean relative humidity in 1983 was generally

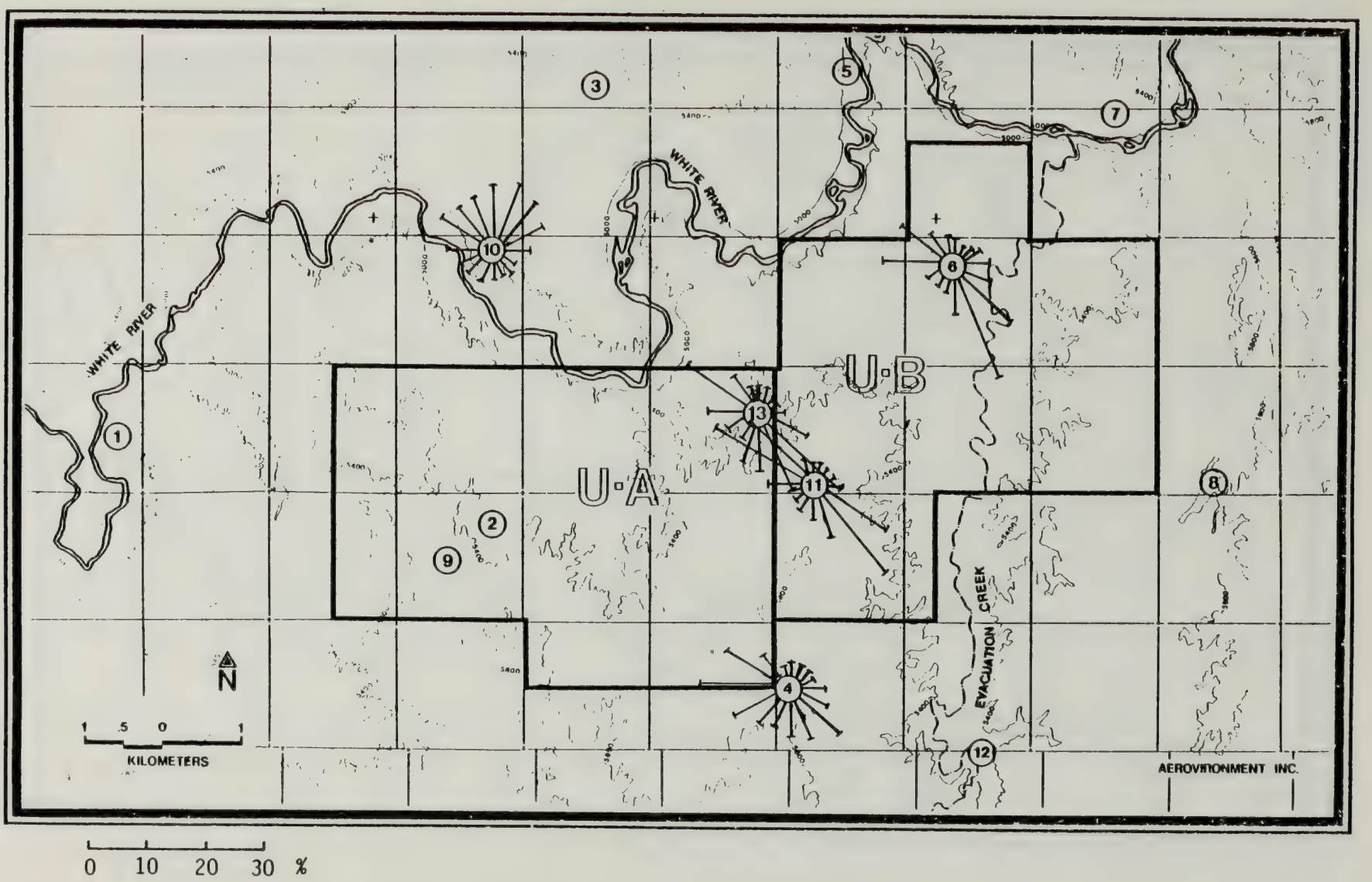


FIGURE 2.4-13. Directional wind roses at the monitoring stations on the tracts for winter 1983. The length of each bar represents the frequency of winds from the direction towards which the bar points.

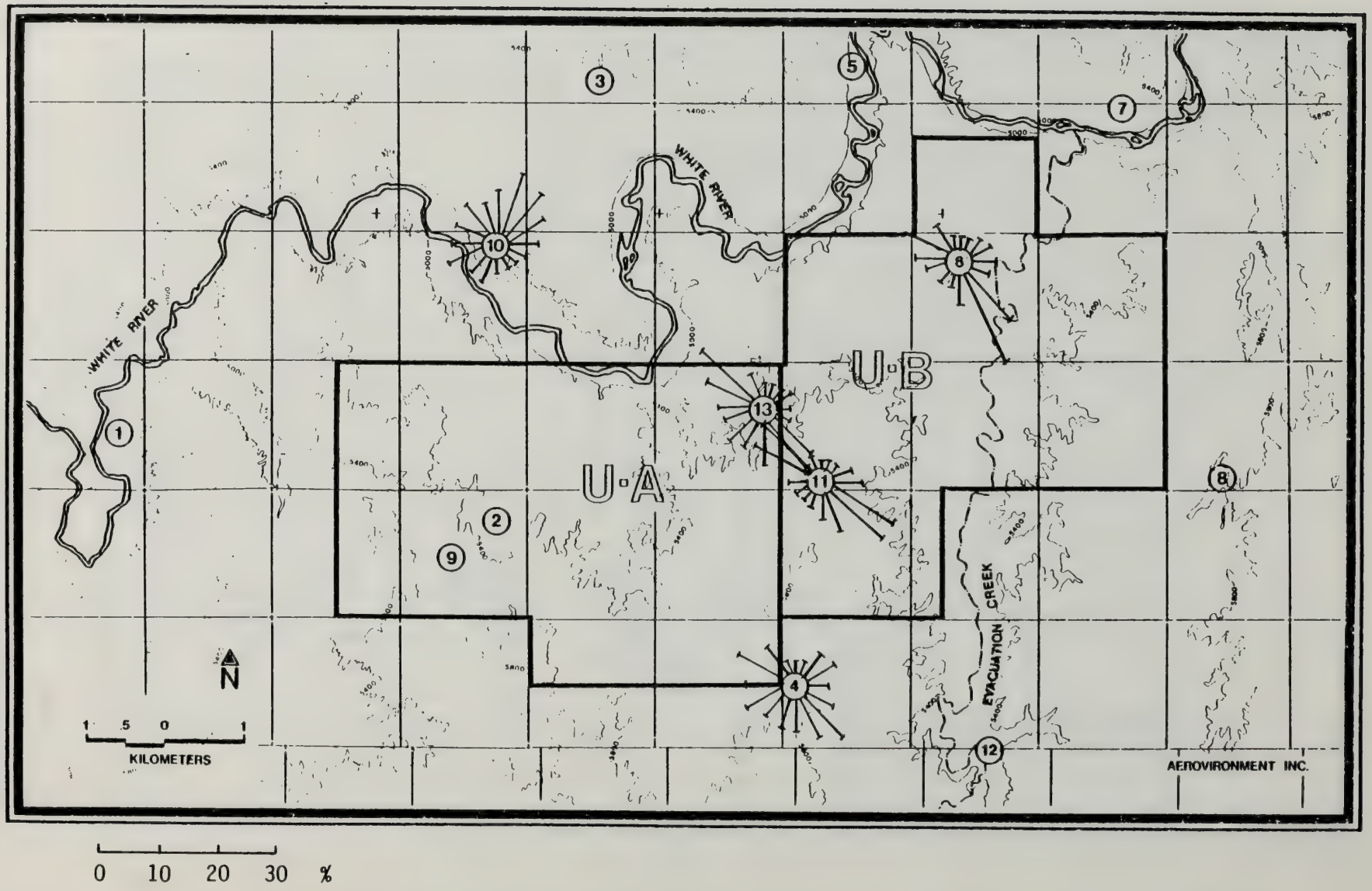


FIGURE 2.4-14. Directional wind roses at the monitoring stations on the tracts for spring 1983. The length of each bar represents the frequency of winds from the direction towards which the bar points.

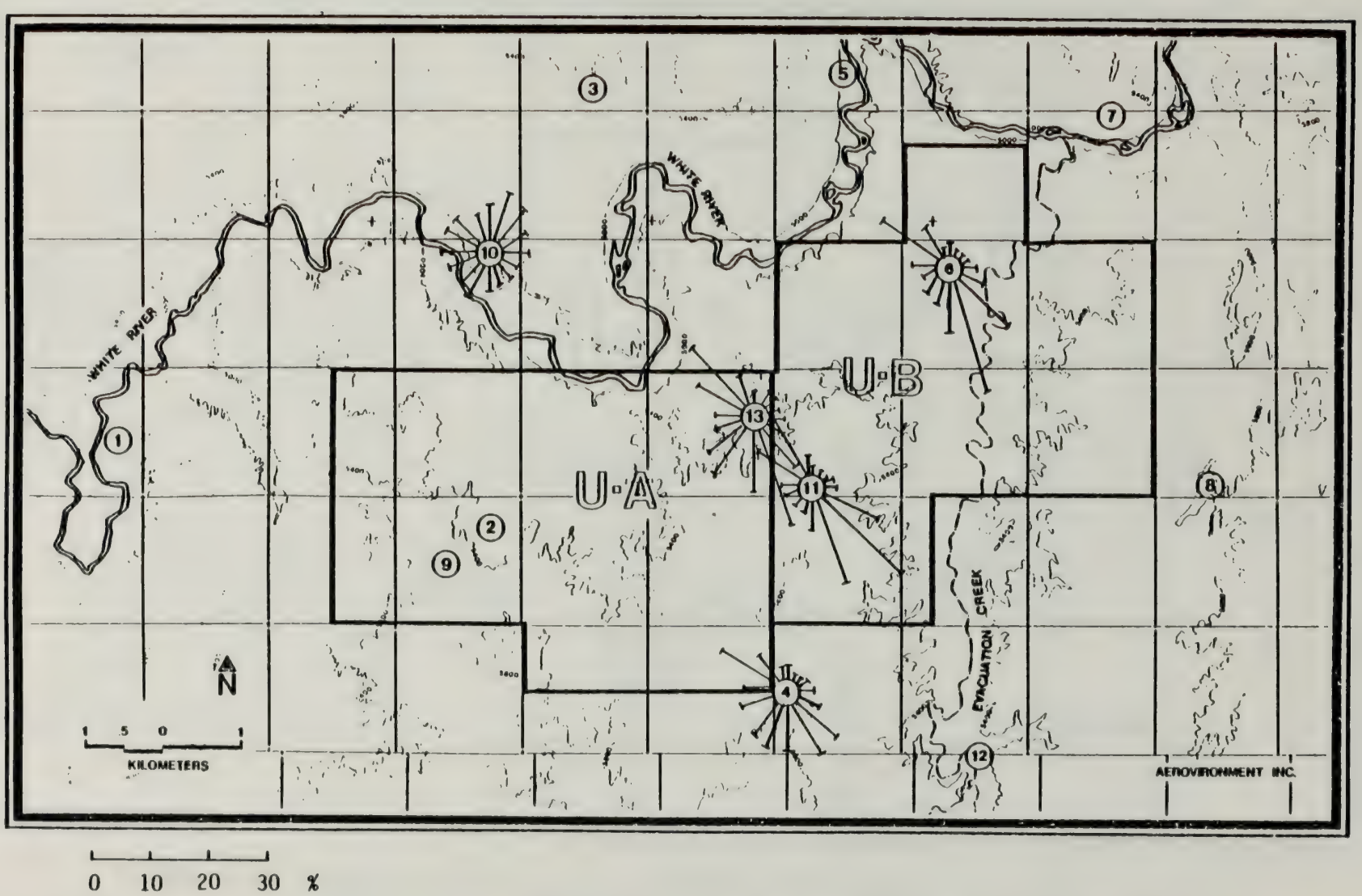


FIGURE 2.4-15. Directional wind roses at the monitoring stations on the tracts for summer 1983. The length of each bar represents the frequency of winds from the direction towards which the bar points.

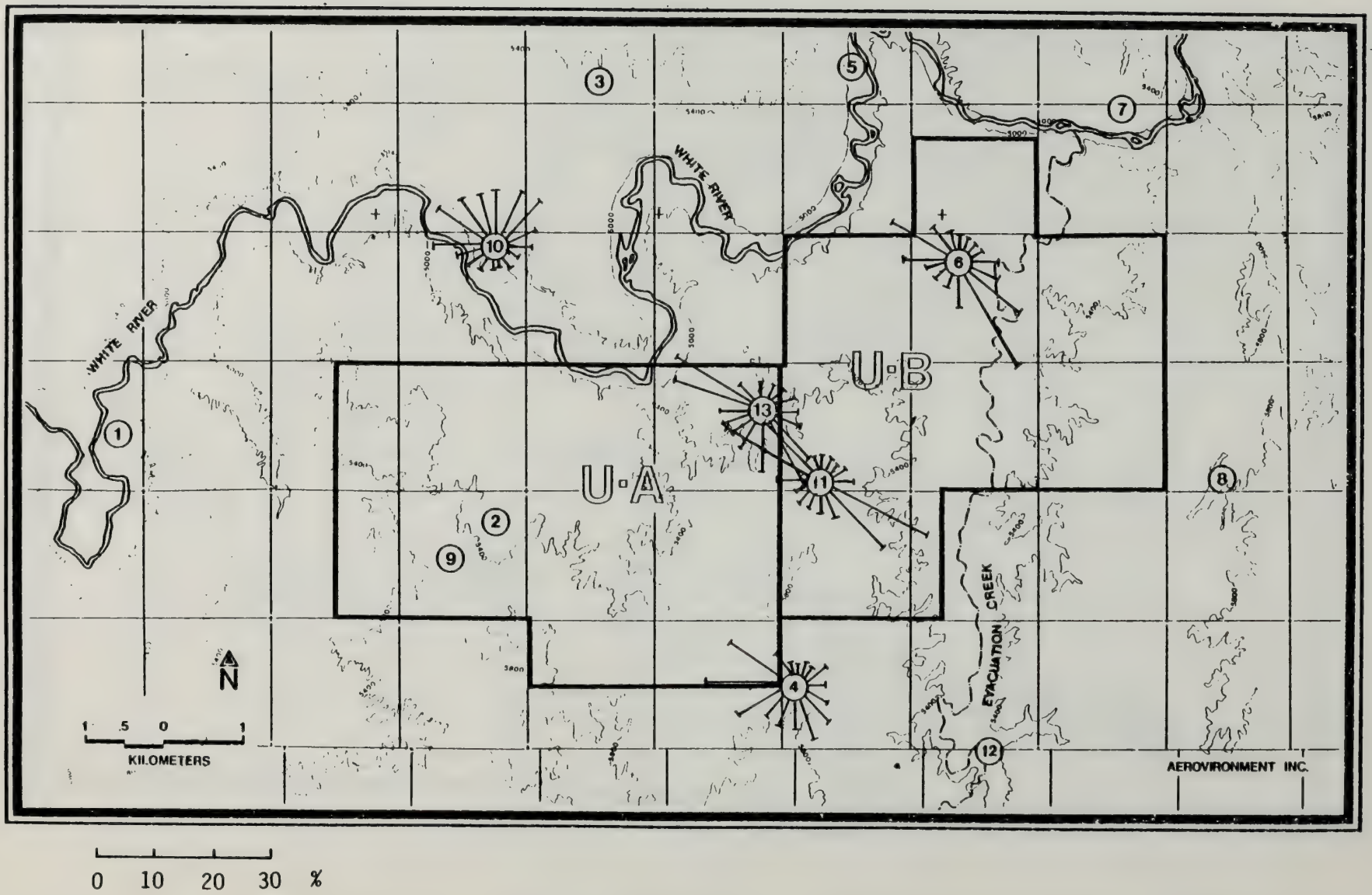


FIGURE 2.4-16. Directional wind roses at the monitoring stations on the tracts for fall 1983. The length of each bar represents the frequency of winds from the direction towards which the bar points.

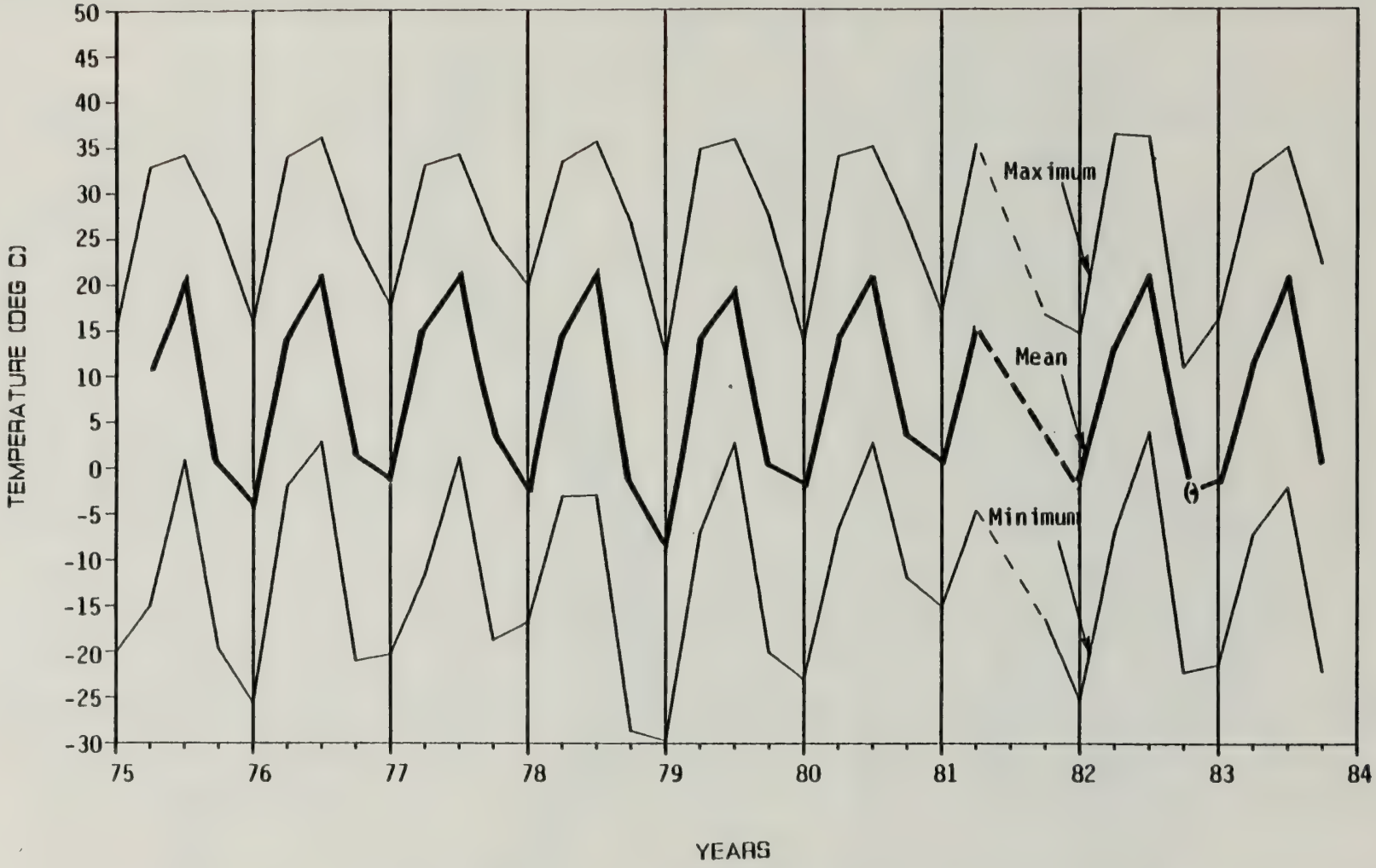


FIGURE 2.4-17. Seasonal maximum, mean, and minimum hourly temperatures (10 m) at A6 for 1975 through 1983. (-) indicates data do not meet EPA (1977) averaging criteria. Dashed lines indicate no data collected.

TABLE 2.4-12. Monthly minimum, mean, and maximum temperatures (^{o}C) for 1983.

Month	A4			A6			A10+			A11			A13		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
JAN	-16.1	-4.0	5.9	-21.6	-6.2	4.0	-9.3*	-3.7*	9.9*	-17.7	-6.7	4.7	--	--	--
FEB	-11.1	-0.9	7.6	-15.1	-2.4	7.1	-16.9	-2.4	10.1	-15.9	-3.3	7.3	-17.5	-3.5	9.9
MAR	-5.4	4.0	16.1	-6.2	3.6	16.3	-2.5*	6.0*	17.8*	-8.4	2.2	16.4	-1.9*	6.6*	18.2*
APR	-6.2	5.2	20.4	-7.2	5.2	21.3	--	--	--	-8.9	4.2	22.1	-6.8*	8.1*	22.6*
MAY	2.8	14.5	27.4	0.1	10.9	27.7	--	--	--	-3.2	10.5	28.9	-1.5	10.4	30.9
JUN	8.4	19.3	31.8	3.5	17.2	32.0	--	--	--	2.2	17.2	34.4	4.7	19.7	35.7
JUL	12.9*	22.3*	32.2*	8.5	21.9	33.7	--	--	--	7.9	22.1	35.7	7.9	23.1	36.2
AUG	13.8	22.6	32.4	11.3	22.8	34.9	--	--	--	11.5	23.8	37.6	11.6	24.8	40.0
SEP	1.0	18.9	31.2	-2.1	18.2	31.5	--	--	--	-1.8	18.3	34.8	-1.1	19.3	34.8
OCT	1.6	11.2	21.4	-2.3	9.8	21.7	--	--	--	-11.4	9.2	23.4	-3.9	9.8	23.4
NOV	-12.7	1.5	15.5	-13.5	0.7	16.3	--	--	--	-15.4	-0.9	15.9	-16.3	-0.2	17.3
DEC	-18.2	-6.8	5.6	-22.0	-8.2	3.2	--	--	--	-23.3	-9.7	6.0	-23.7	-9.0	4.7
Annual	-18.2	9.0	32.4	-22.0	7.8	34.9	--	--	--	-23.3	7.2	37.6	-23.7	10.5**	40.0

+A10 temperature instrument removed 3/14/83.
*Low data recovery.
**Based on nine (9) months of complete data.
-- No data recovered.

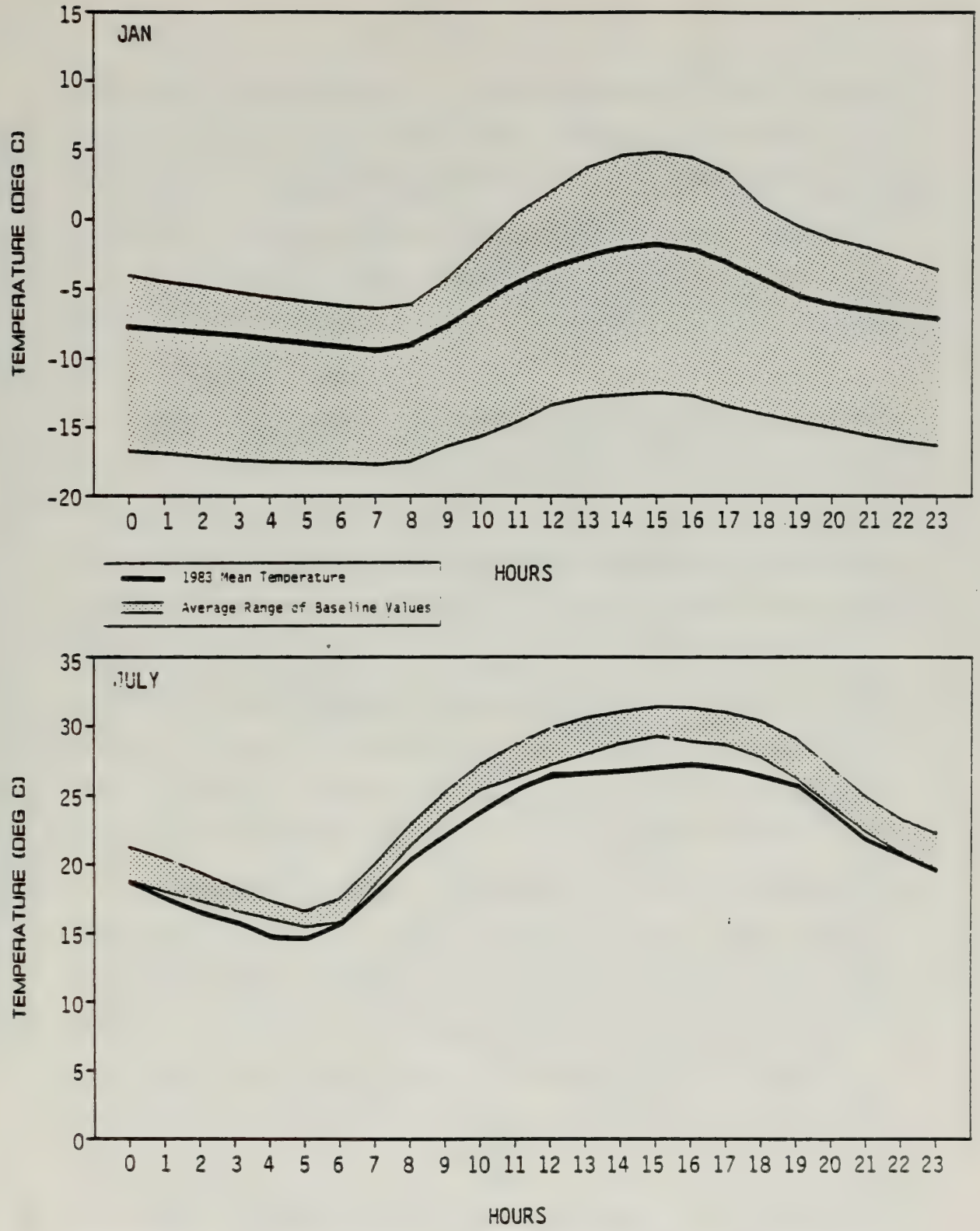


FIGURE 2-4-18. Monthly averaged January and July hourly temperatures (10 m) in 1983 versus baseline for Site A6.

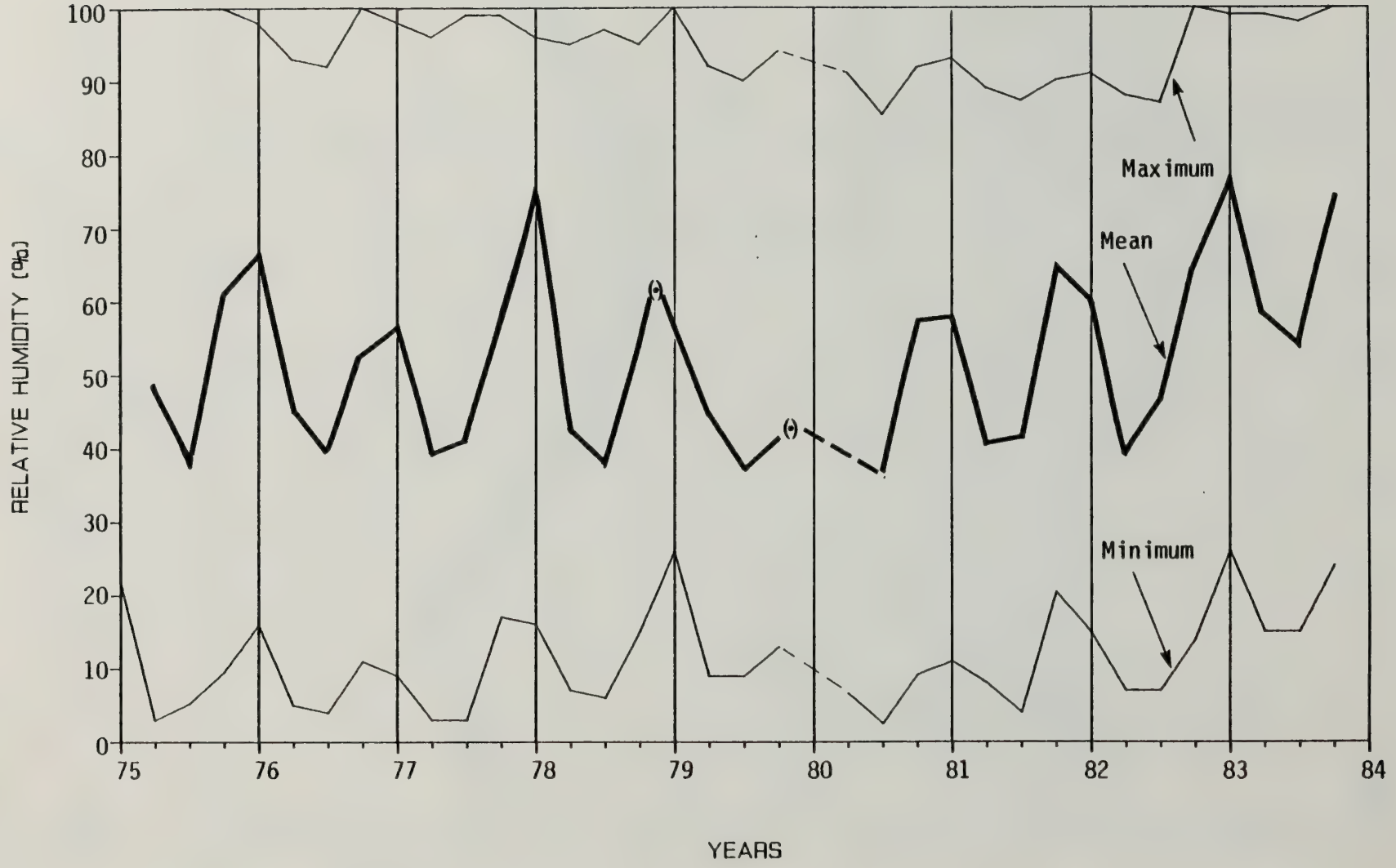


FIGURE 2.4-19. Seasonal maximum, mean, and minimum relative humidity at A6 for 1975 through 1983. (·) indicates data do not meet EPA (1977) averaging criteria. Dashed lines indicate no data collected.

higher than in previous years. As mentioned in the climatic summary, 1983 was an abnormal year, with higher than normal precipitation. This year does show the normal seasonal distribution, however, with the lowest humidities in spring and summer and the highest in winter and fall.

The 1983 monthly values of relative humidity versus baseline at A6 are given in Table 2.4-13. The values for the year range from 100% to 15%. The annual mean is 66%.

Figure 2.4-20 compares the January and July 1983 diurnal relative humidity distribution with the average baseline range of values. January recorded morning and evening relative humidity that was above the baseline range. This may be due to residual ground moisture from a stormy November and December 1982. July had consistently higher than baseline relative humidity throughout the day, probably due to moisture from a very wet spring and a cooler than normal July. The diurnal variation of relative humidity is approximately the reciprocal of temperature, indicating that the amount of moisture in the air remains fairly constant during the day on the tracts.

D. Barometric Pressure Figure 2.4-21 plots Site A6 seasonal barometric pressure for 1975 to 1983. In general, severe winter storms produce the lowest pressures and the basin high pressure cells produce the highest readings. During summer, the pressure systems that influence Utah are much weaker, resulting in fewer pressure extremes.

Table 2.4-14 lists Site A6 monthly averaged barometric pressure for 1983 and the baseline period. The storminess experienced in January through April, November and December is reflected in significantly lower

TABLE 2.4-13. Monthly minimum, mean, and maximum relative humidity (%) for 1983 versus baseline (1975-1981) at A6.

Month	Baseline			1983		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
January	18	72	100	41	82	98
February	9	65	100	39	79	99
March	10	60	100	26	70	99
April	3	47	100	17	60	97
May	5	47	100	15	58	99
June	4	34	100	18	56	99
July	3	37	100	15	52	97
August	4	39	100	22	56	98
September	9	43	100	21	54	98
October	9	51	100	29	65	100
November	15	60	100	24	77	99
December	11	68	100	38	80	96
Annual	3	52	100	15	66	100

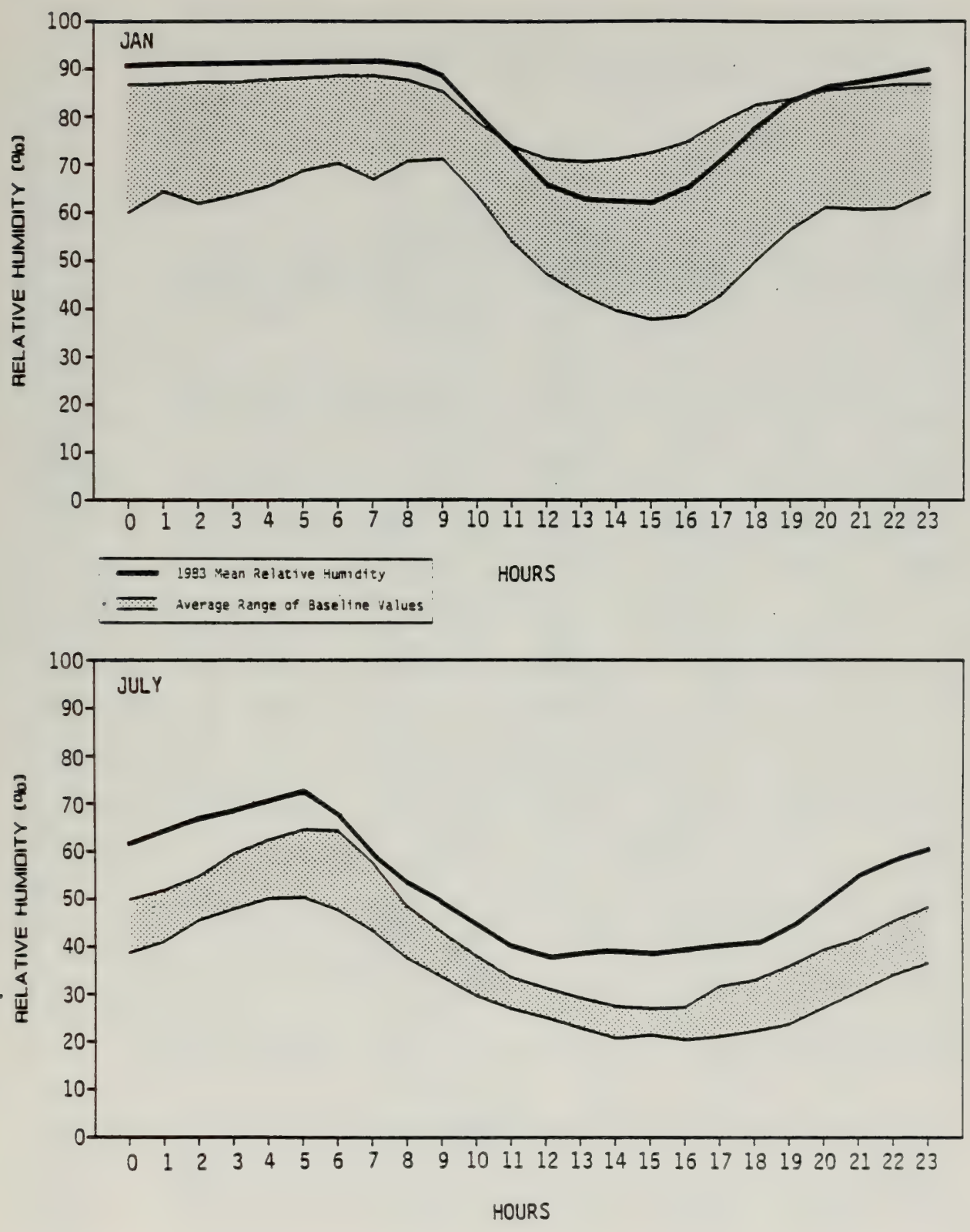


FIGURE 2.4-20. Monthly averaged January and July hourly relative humidity in 1983 versus baseline for Site A6.

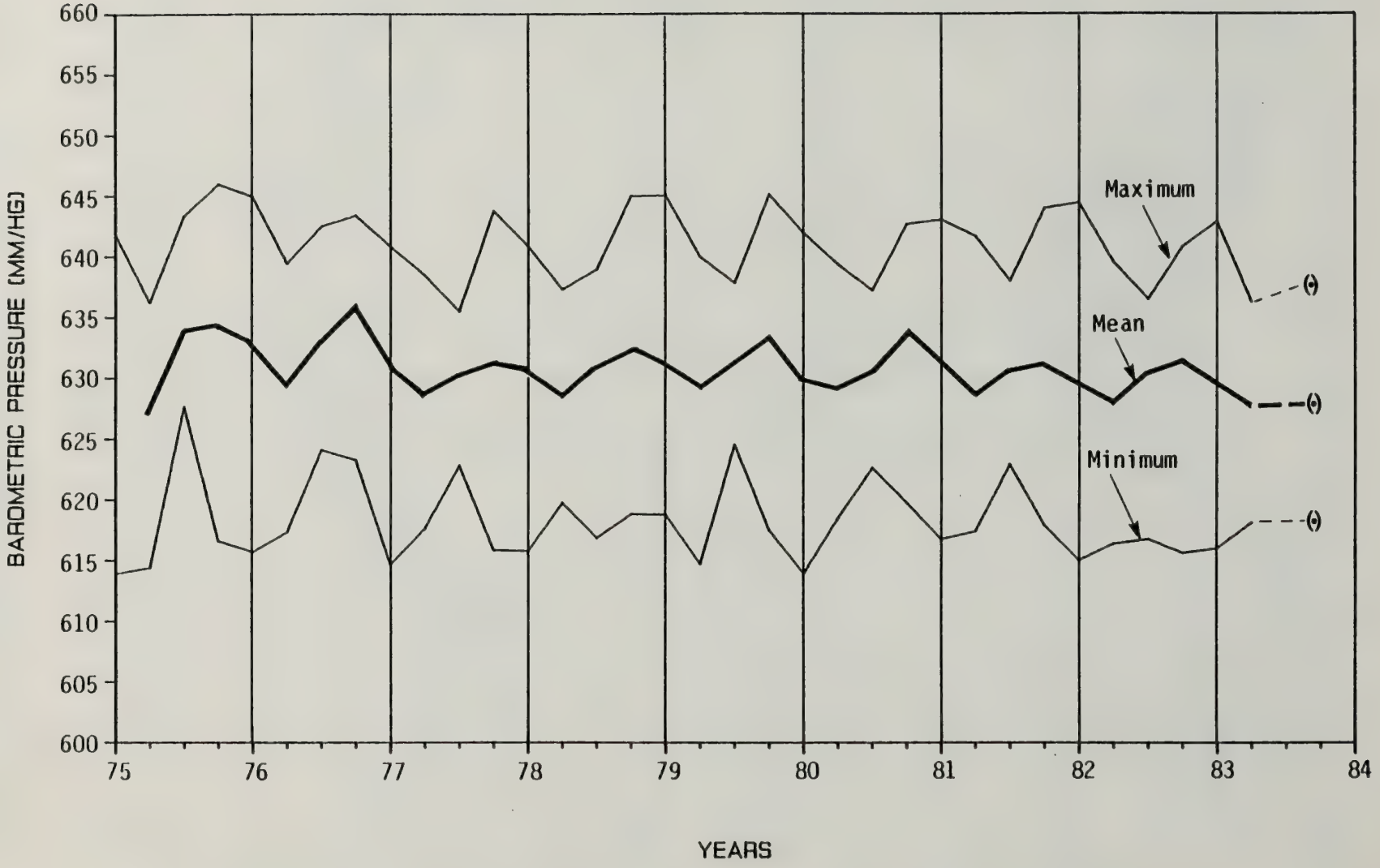


FIGURE 2.4-21. Site A6 seasonal barometric pressure for 1975 through 1983. (•) indicates data do not meet EPA (1977) averaging criteria. Dashed lines indicate no data collected.

TABLE 2.4-14. Monthly minimum, mean and maximum barometric pressure (mm of Hg) for Site A6 for 1983 and baseline (1975-1981).

	Baseline			1983		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
January	614	632	645	623	632	643
February	616	632	645	621	630	637
March	614	628	641	616	626	636
April	614	629	642	619	627	636
May	616	628	638	618	628	635
June	616	629	640	618	628	636
July	623	631	638	--	--	--
August	623	631	640	--	--	--
September	617	632	643	--	--	--
October	617	632	643	--	--	--
November	616	633	646	613	626	636
December	617	633	645	617	628	639
Annual	614	631	646	613	628	643

-- Power supply for barometer damaged by power surge due to electrical storm; instrument out for repair.

than normal barometric pressures for those months. May and June recorded near normal barometric pressures.

E. Net Thermal Radiation Figure 2.4-22 plots A6 diurnal net thermal radiation for January and July 1983 versus the baseline range. As expected, the radiation is higher in summer due to the longer periods of sunshine, more intense sunlight and less cloudiness. Highest values generally occur around noon when the sun is at its apex.

January and July 1983 midday values fell within the baseline range of values. July 1983 mornings and evenings experienced less negative radiation due to an abnormally stormy July. Cloud cover does not allow as much negative radiation to pass from ground to sky as does a clear sky.

2.4.2.3 Diffusivity When a pollutant in the form of a plume or puff is released into the atmosphere, it is transported by the prevailing wind. As it travels downwind, its concentration decreases as its volume increases. Its growth in the vertical is governed mainly by the atmospheric stability, while its growth in the horizontal depends upon both stability and turbulence.

A. Turbulence Mechanical turbulence is defined as the irregular and apparently random fluctuations in air velocities induced by surface roughness. An indicator of mechanical turbulence is the fluctuation of wind direction, or sigma theta (σ_θ).

Using σ_θ data from Site A6, the frequency distribution of different diffusion classes is computed in Table 2.4-15. The classification scheme used follows that in the Atomic Energy Safety Guide 23 (AEC, 1972) and

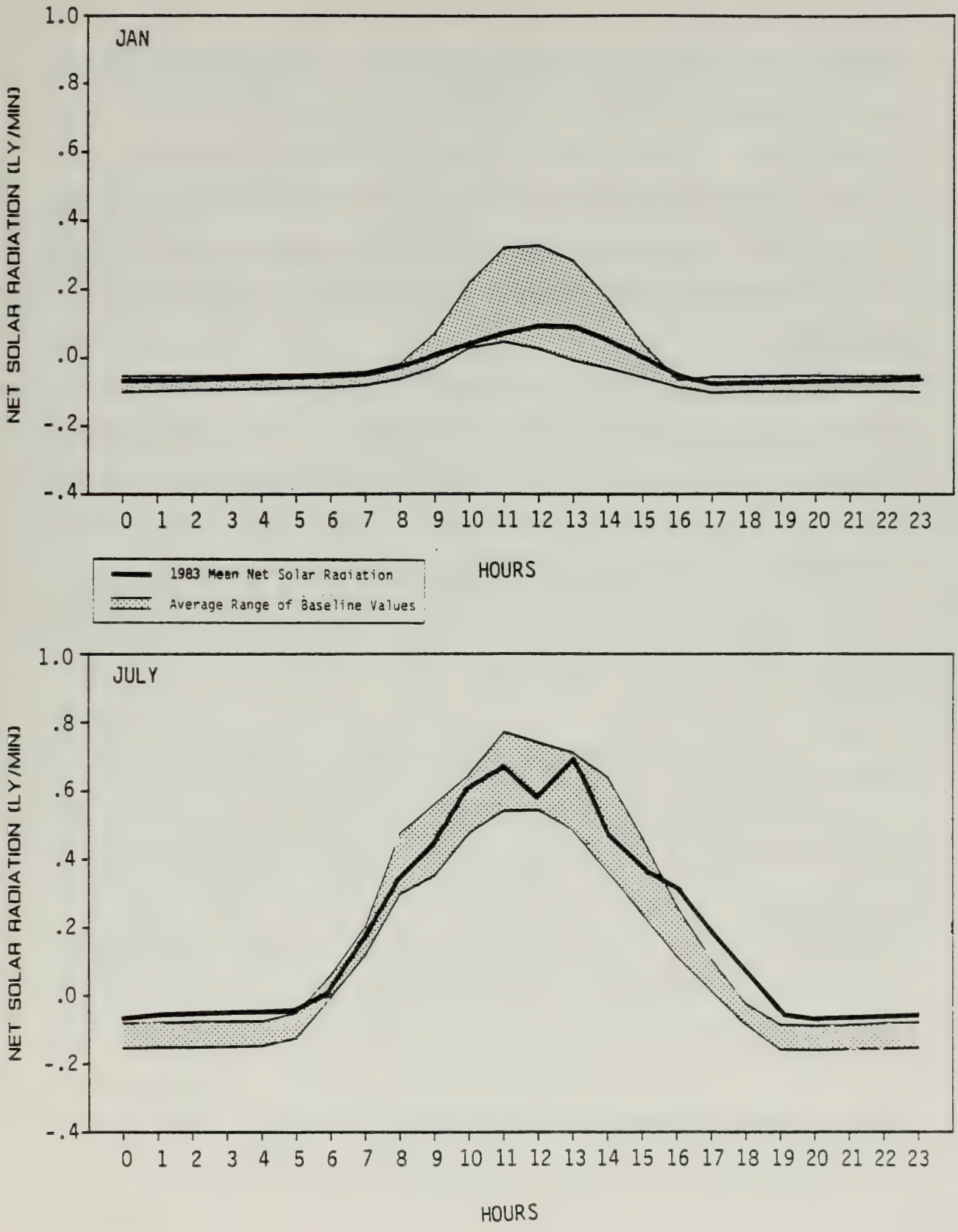


FIGURE 2.4-22. Monthly averaged January and July hourly net thermal radiation in 1983 versus baseline for Site A6.

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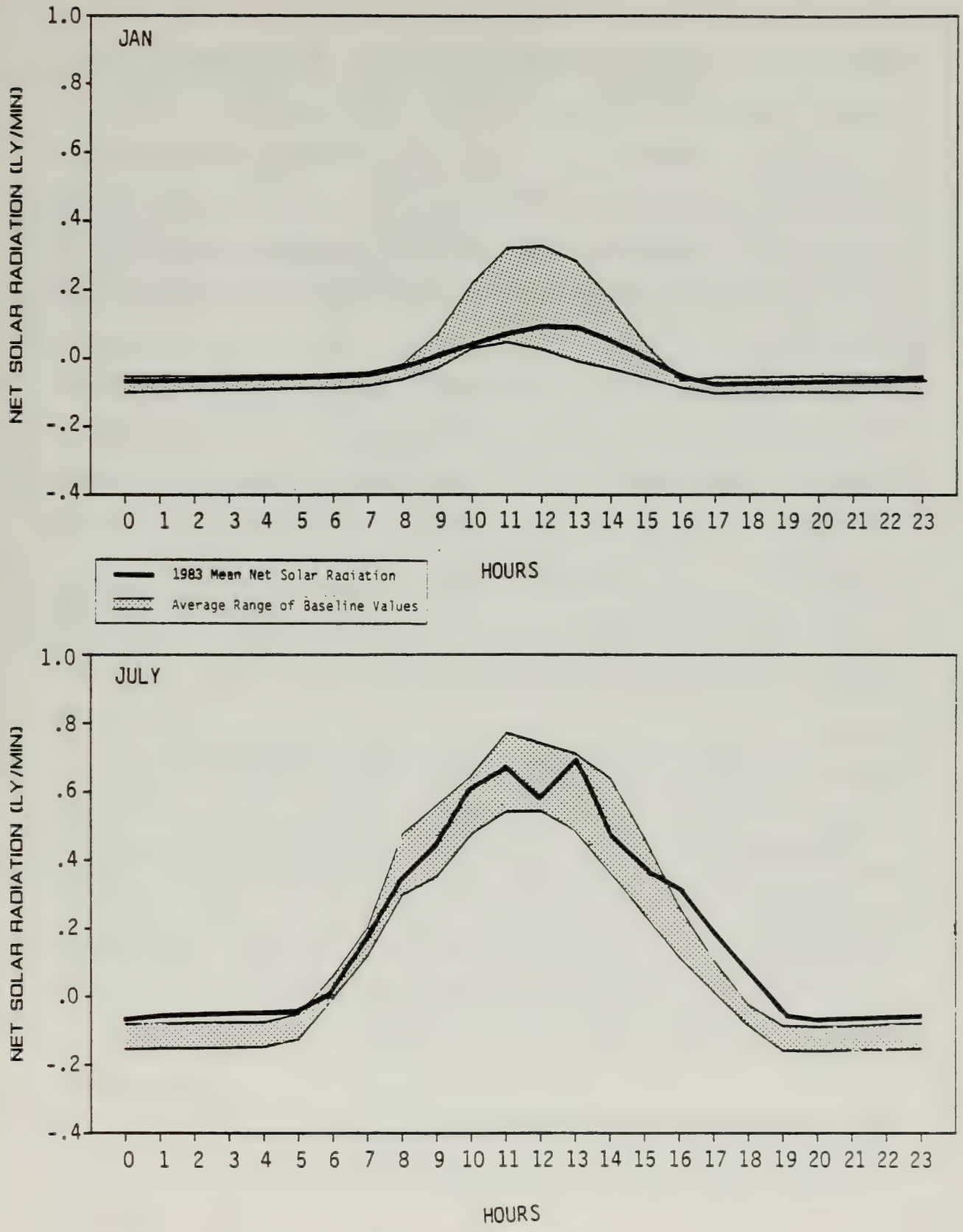

FIGURE 2.4-22. Monthly averaged January and July hourly net thermal radiation in 1983 versus baseline for Site A6.

TABLE 2.4-15. Relative frequency distribution (%) of diffusion classes using σ_θ at A6 during 1983 and the baseline period.

Season	Class							Total No. of Observations
	A	B	C	D	E	F	G	
1975-1981								
Winter	3.2	5.4	15.1	38.0	34.7	3.3	0.3	12,826
Spring	6.2	8.9	15.8	37.0	30.2	1.9	0.0	12,812
Summer	4.8	9.2	19.0	33.7	30.8	2.5	0.0	13,031
Fall	3.2	6.4	16.9	34.1	34.3	4.8	0.3	15,126
All seasons combined	4.3	7.4	16.7	35.6	32.6	3.2	0.2	53,795
1983								
Winter	0.0	.6	6.2	26.7	44.2	13.1	9.5	2,156
Spring	0.0	2.9	12.5	31.8	35.3	10.7	6.7	2,152
Summer	1.5	3.0	8.5	30.6	40.2	11.6	4.6	1,416
Fall	0.0	.2	5.1	28.1	50.3	11.6	4.7	2,196
All seasons combined	0.3	1.6	8.0	29.2	42.7	11.7	6.5	7,920

NOTE: Table 2.4-16 defines classes A-G.

appears in Table 2.4-16. During the baseline, stable cases (E, F, and G) were the most prevalent (36%), followed by neutral (D) conditions (35.6%), with unstable (A, B, and C) occurring the least (28.4%). In 1983, the pattern was similar except that the differences between the three groups are much larger, at 60.9%, 29.2%, and 9.9%, respectively. Stable cases are more prevalent in the winter and fall, associated with lower wind speeds.

The diurnal distribution of σ_θ at A6 in January and July appears in Figure 2.4-23. It is evident from the figure that both months had low values of sigma theta, thus small variation in short-term wind direction. In other words, there was less fluctuation in the wind direction for January and July than in corresponding baseline months at Site A6. However, the instrument recording sigma theta was out for repair from July 8 to July 31, so we can draw only tentative conclusions for this month.

The predominance of stable conditions in January 1983 (more so than during baseline) is likely related to a greater persistence of drainage flows in that month. Figure 2.4-12 showed lower than normal wind speeds and Table 2.4-11 showed SE as the prevailing direction for January 1983. Also, this month had a greater number of weather disturbances than usual, making the synoptic flows less dominant. The solar radiation needed to break-up the drainage conditions was also slightly below normal.

The diurnal distributions do show that the most stable cases occur in the mornings, associated with drainage conditions, in both January and July.

TABLE 2.4-16. Classification of atmospheric diffusivity using σ_θ.

Stability Classification	Pasquill Categories	σ_θ* (Degrees)
Extremely unstable	A	>22.5
Moderately unstable	B	17.5-22.5
Slightly unstable	C	12.5-17.5
Neutral	D	7.5-12.5
Slightly stable	E	3.5-7.5
Moderately or very stable	F	2.0-3.5
Extremely stable	G	0-2.0

Source: Atomic Energy Safety Guide 23 (AEC, 1972).

*Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to one hour.

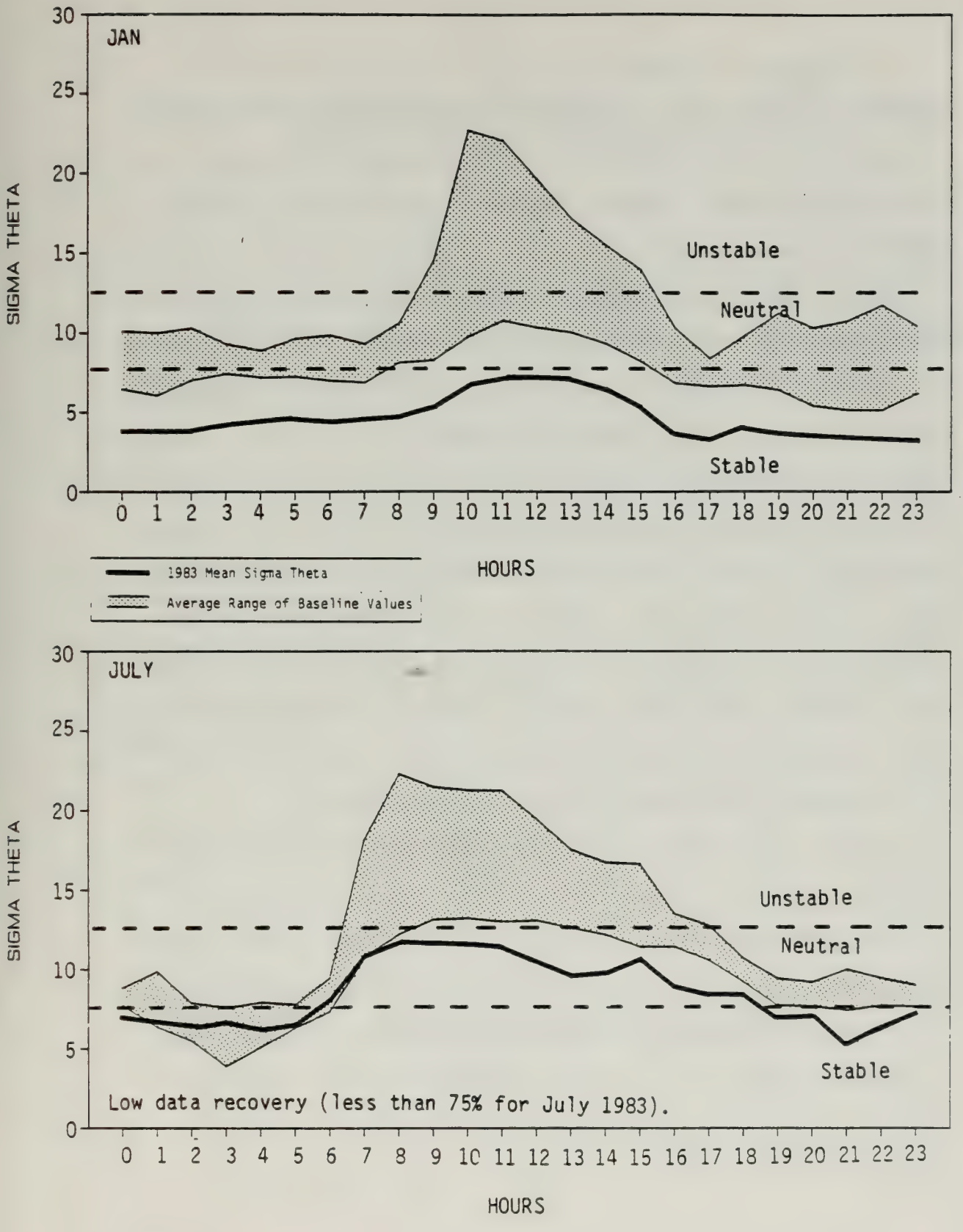

FIGURE 2.4-23. Diurnal distribution of σ_θ at Site A6 for January and July 1983 versus baseline.

B. Stability A complete dispersion picture must also include the effect of plume rise. The meteorological parameters that greatly influence the height of a plume are vertical atmospheric (thermal) stability and wind speed. Vertical atmospheric stability can be approximated by ΔT data.

In equations derived by Briggs (1974) for calculating plume height, only three atmospheric stability classes are needed. Table 2.4-17 shows the frequency distribution of each of these three classes, based on seasonal ΔT data for both 1983 and baseline ΔT data by season. The classification scheme for these stabilities follows in Table 2.4-18.

Using this classification method, all three classes occur approximately one third of the time in the baseline, but the neutral/unstable category jumps to 50% in 1983. While the 1983 σ_θ data show more stability due to less turbulence, the ΔT data show less stability due to weaker inversions and/or better mixing in 1983. Like the diffusion classes, the very stable cases usually occur most frequently in the fall and winter, when stronger inversions generally exist.

Figure 2.4-24 shows the diurnal variation of ΔT at A6 in January and July. Generally, a temperature inversion forms at night, as the air cools more quickly than the ground, leaving a stable layer. Warming during the day eventually breaks the inversion, allowing for freer mixing. In July, the warming occurs earlier and lasts later into the day than in January, allowing more time for unstable conditions to take over. In 1983, the ΔT means (unlike sigma theta) fall within the baseline range of values.

TABLE 2.4-17. Relative frequency distribution (%) of stability classes using ΔT at A6 during 1983 and the baseline period.

Season	Unstable or Neutral <-0.5	Slightly Stable -0.5-1.5	Very Stable >1.5	Total Number of Observations
1975-1981				
Winter	39.0	25.7	35.3	14,578
Spring	44.4	29.8	25.8	14,745
Summer	37.4	30.0	32.6	13,233
Fall	37.8	22.8	39.4	14,633
All seasons combined	39.7	27.0	33.3	57,189
1983				
Winter	47.0	27.2	25.8	2,157
Spring	56.6	24.9	18.5	2,163
Summer	45.9	26.3	27.8	2,205
Fall	52.4	22.8	24.8	2,199
All seasons combined	50.5	25.3	24.2	8,724

TABLE 2.4-18. Classification of atmospheric stability using ΔT.

Stability	ΔT ($^{o}C/20$ m)
Unstable and Neutral	<-0.1
Slightly Stable	-0.1 to 1.3
Very Stable	>0.3

Source: Briggs, 1974.

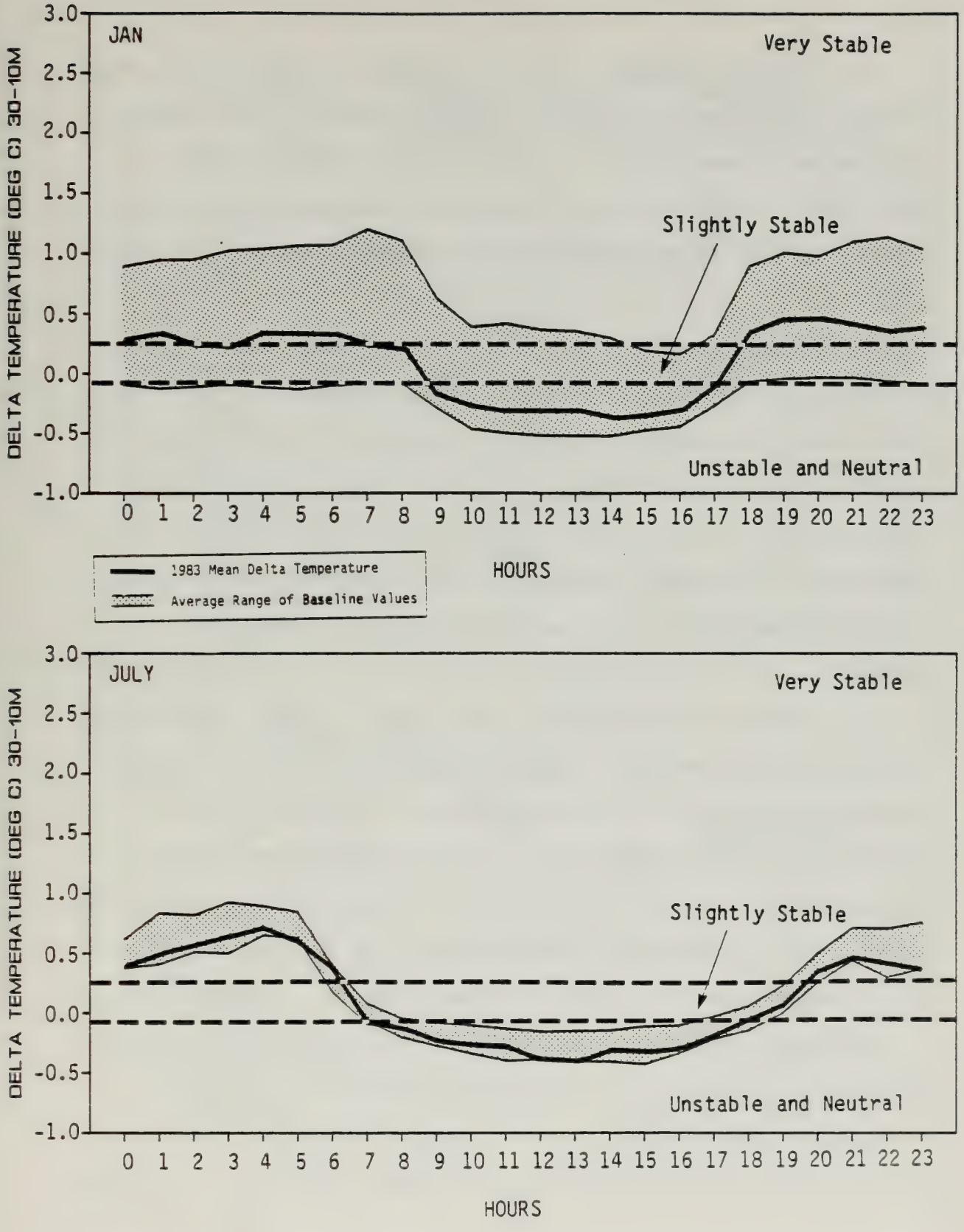

FIGURE 2.4-24. Diurnal variation of ΔT at Site A6 for January and July 1983 versus baseline.

C. Pollution Potential The diffusion data are significant because the stable situations are generally associated with the lowest dispersion, and hence have the greatest potential for pollution impacts. Since stable conditions occur in the tracts more than 30% of the time (whether based on ΔT or σ_θ), this area has a fairly high pollution potential.

As a further measure of this potential, pollutants tend to build up even more under stable conditions when the wind speed is low. Table 2.4-19 shows the seasonal frequency of the combined stable/low wind speed factors. When compared to Tables 2.4-15 and 2.4-17, it can be seen that almost all of the very stable cases are associated with low wind speeds. The highest frequency of this combination occurs in winter, meaning the possibility of air quality impact during this season is greatest.

Low winds and stable conditions occur mostly at night, when drainage wind patterns are prevalent. For the tracts, these winds would carry the emissions down the drainage valleys and along the White River. Station A10 was sited along the river to detect any of these impacts. So far, most construction activities occur during the daytime when mixing is better, so no impacts have been observed. Once operation begins, gaseous pollutant monitoring will also be added.

The control measures planned, as well as the higher precipitation and the lower solar radiations in winter, should ameliorate impacts during these stable periods. However, these conditions will continue to be monitored closely to assure the best protection for the environment.

TABLE 2.4-19. Relative frequency of low wind speed (<3.5 m/s) combined with very stable atmospheric conditions in 1983 at Site A6.

a. Stability based on $\Delta T > 1.5^{o}C/100$ m

Season	Frequency (%)	Total Observations
Winter	27.2	586
Spring	16.8	362
Summer	26.3	580
Fall	25.4	559
All year	24.0	2,087

b. Stability based on $\sigma_{\theta} \leq 3.5$

Season	Frequency (%)	Total Observations
Winter	21.7	470
Spring	13.6	292
Summer	14.2	202
Fall	16.1	354
All year	16.4	1,318

2.4.2.4 Atmospheric Data Summary Table 2.4-20 presents the annual averages of each of the meteorological parameters discussed in the previous sections. This table summarizes the means of these data for each of the years monitored. As with air quality, there is only slight variation from year to year in the overall means, with no definite patterns among the parameters. Even the overall averages show that 1983 was an unusual year, with slightly lower wind speeds, barometric pressure and turbulence (σ_θ) and higher relative humidity.

2.4.3 Sound levels

Peak and average quarterly sound levels for 1981 -- when sound measurements resumed -- to 1983 are shown in Table 2.4-21. Sound level measurements show that the most remote site, Asphalt Wash, has the lowest sound levels (20-40 dB(A)); on-tract sites (A4 and A6) and the site along the river (A10) have slightly higher levels (20-50 dB(A)); and levels along the roadway (Highway 45 and Ignacio) are the highest (20-75 dB(A)). Noise is fairly constant from season to season at these sites. These values also correspond to measurements made in 1975 when a range of 20-60 dB(A) was recorded on tract.

Most background noise on the tracts is from natural sources -- insects, rustling grass, and wind -- and the noise level from these is somewhat variable. Another natural source, which affects certain areas, is the water running in the White River. Noise from the construction activities in the area adds to this background, as well as traffic along the roads.

TABLE 2.4-20. Annual averages of the meteorological parameters measured during the entire monitoring period at A6.

	Wind Speed (10 m) (mph)	Temperature (10 m) (^{o}C)	Relative Humidity (%)	Barometric Pressure (mm HG)	Solar Radiation (ly/min)	ΔT (30-10 m)	σ_{θ} (30 m)
1975	8.9	8.3	52.6	631	(0.07)	0.67	(--)
1976	9.4	8.1	51.1	633	0.09	0.01	9.0
1977	6.9	9.8	48.9	630	0.08	0.14	10.2
1978	6.3	7.8	51.2	631	0.06	0.14	10.0
1979	6.5	6.3	(61.0)	631	(-0.05)	0.16	10.8
1980	6.9	9.1	(45.0)	631	0.03	0.09	12.1
1981	6.5	(6.2)	51.2	630	0.06	(0.14)	10.9
1982	6.0	8.2	52.4	630	-0.05	0.14	9.0
1983	4.9	8.1	66.0	(628)	0.07	0.04	7.5

() Average based on data of insufficient quantity to meet EPA (1977) criteria.

-- Low data recovery.

TABLE 2.4-21. Summary of peak and average sound level data for 1981-1983.

Site	Year / Quarter	Peak Sound Levels (dB(A))									Average Sound Levels (dB(A))								
		1981	1982				1983				1981	1982				1983			
		4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1. Hwy 45	(a.m.)	30	27	57	48	76	30	36	37	30	≤25	≤23	31	≤34	≤33	≤23	≤39	≤25	≤22
	(p.m.)	42	29	50	54	52	40	45	40	40	25	25	30	38	≤29	≤24	≤28	≤27	27
2. Ignacio	(a.m.)	47	57	68	66	53	47	47	40	42	35	28	47	49	40	31	35	35	33
	(p.m.)	46	37	74	67	50	32	37	42	42	32	27	49	47	36	25	31	31	31
3. Site A4		37	41	51	25	45	35	33	34	32	23	≤24	≤29	≤21	≤24	≤23	≤24	≤23	23
4. Site A6		35	25	47	43	44	47	37	48	33	27	23	33	31	28	29	≤23	26	≤24
5. Site A10		32	28	37	30	32	32	35	38	39	≤23	≤22	≤25	≤22	≤25	≤24	≤24	≤25	29
6. Asphalt Wash		--	--	40	22	43	--	23	30	--	--	--	≤24	≤21	≤24	--	≤21	≤22	--
No. Readings/Site*		12	12	13	11	14	13	12	14	13	12	12	13	11	14	13	12	14	13

*Some readings not taken at Asphalt Wash due to weather.
(≤)Averages contain readings of 20dB(A) at the lower end of the instruments scale.

The peak reading in 1983 was 48 dB(A) at station A6. This site is very close to the road where most construction traffic passes. The average readings in 1983 ranged from 20-40 dB(A), which is typical of rural background sound levels. These levels are somewhat lower than the ones measured in 1982.

2.4.4 Special Studies An important aspect of air quality is the relationship of relevant atmospheric processes to the total ecological system. To this end, special studies have been and will be conducted from time to time as part of the environmental monitoring program. Topics or areas of study are picked based on current environmental issues and/or areas of interest to White River Shale Oil Corporation. Both rainfall chemistry and low-level temperatures were considered such topics and were chosen for study in 1983.

2.4.4.1 Rainfall Chemistry Because of the increased concern that acid deposition may be a serious environmental problem, several precipitation monitoring studies have been performed, with various conclusions as to the source and the long-range transport effects. During 1983, several rainfall samples were collected at the A4 site for chemical analysis. The objective was to obtain additional "baseline" information on rainfall chemistry, especially contributions, if any, to acid deposition in the Unita Basin from long-range transport, local sources, and natural sources. To investigate the effects of all contributing factors, specific consideration was given to meteorology, ambient air quality, pH, conductivity and ionic species.

A. Experiment Description Rainfall samples were collected at the A4 ambient air monitoring site. Samples were collected in the regular site rain gauge lined with a 1,000-ml, polypropylene, conical graduated cylinder. The site was not manned continuously, resulting in several periods of uninterrupted sampling instead of sampling each individual rainfall event. The cylinder was multiply washed with distilled/deionized water after each sample was removed and prior to the next sample collection period.

The samples collected were stored in pre-washed polypropylene bottles and refrigerated until analysis could be performed. A total of twenty samples were collected, with six being replicates of the same storm.

B. Sample Analysis The conductivity of each sample was determined using a Horizontal Model 1484-10 conductivity meter. The pH was determined using an Orion Research Model 501 Digital Ionanalyzer with an Orion Model 91-05 combination pH electrode. Before pH analysis, the samples were spiked with a buffer solution of reagent grade potassium chloride (KCl) to increase the ionic strength, following the method of Galloway, et al. (1979). The samples were agitated and then allowed to settle before pH readings were taken.

Analysis for the anions CL^-, NO_3^-, $SO_4^=$, Br^-, F^-, PO_4^{3-}, and NO_2^- were performed by a Dionex Model 14 Ion Chromatograph.

C. Quality Control The conductivity meter was calibrated before and after each set of analyses, using a conductivity standard solution with an equivalent output of 1,990 micromhos that was supplied by the instrument manufacturer.

The pH meter was calibrated using Scientific Products reference buffer solutions of pH 4.01, 5.0, and 6.0. Each solution is traceable to National Bureau of Standards Standard Reference Material 185. The pH electrode was stored immersed in the 5.0-pH buffer solution. The output of the pH meter was checked after every third sample was analyzed.

Quality control of anion analysis was done with blind spiked samples (Table 2.4-22) and actual rain sample duplicates (Table 2.4-23). The percent recovery of the blind spiked samples in Table 2.4-22 ranged from 91% to 122%; a range of 93% to 107% is considered acceptable. The sample outside this range (182) was reanalyzed as shown in Table 2.4-22 with other results falling within tolerances.

The percent difference between duplicate sample data in Table 2.4-23 ranged from -264% to 104%. Although this seems like a tremendous range, small differences in these very low concentrations will have a significantly disproportionate large percentage. For the Dionex analyzer, PO_4 is used as the reference peak because of the low level expected. Although not shown, percents were calculated based on at least five significant digits. The data actually shows good agreement for this type of measurement.

The stock quality control standards used in calibrating the ion chromatograph were analyzed against EPA reference quality control samples.

D. Results The results of the experiment are presented in Table 2.4-24. Each of the storms was characterized as one of three air mass types (Table 2.4-25). The subtropical air mass occurred in five of the fourteen rain events. This air mass generally originated in the Gulf of

TABLE 2.4-22. Quality control data - spiked sample data.

Analysis ID	Date Analyzed	Analyte	Found µg/ML	Expected µg/ML	% Recovery
182	342	F	0.08	0.1	99.7
181	342	F	0.56	0.6	94.9
180	342	F	3.81	3.8	101.8
182	343	F	0.08	0.1	91.5
182	343	F	0.09	0.1	104.7
181	343	F	0.62	0.6	103.6
181	343	F	0.59	0.6	98.8
180	343	F	3.74	3.8	99.9
180	343	F	3.76	3.8	100.4
182	342	CL	0.14	0.1	117.4
181	342	CL	0.76	0.8	95.2
180	342	CL	5.07	5.0	101.4
182	343	CL	0.14	0.1	120.8
182	343	CL	0.12	0.1	108.0
181	343	CL	0.82	0.8	103.5
181	343	CL	0.85	0.8	106.8
180	343	CL	4.98	5.0	99.7
180	343	CL	5.03	5.0	100.6
182	342	PO_4	0.54	0.6	91.3
181	342	PO_4	3.78	4.0	94.6
180	342	PO_4	25.02	25.0	100.1
182	343	PO_4	0.58	0.6	97.9
181	343	PO_4	4.11	4.0	102.9
181	343	PO_4	3.94	4.0	98.6
180	343	PO_4	24.63	25.0	98.5
180	343	PO_4	24.87	25.0	99.4
182	342	NO_3	0.58	0.6	97.7
181	342	NO_3	3.75	4.0	93.7
180	342	NO_3	26.10	25.0	104.4
182	342	NO_3	0.62	0.6	104.6
182	343	NO_3	0.72	0.6	121.6
182	343	NO_3	0.59	0.6	98.5
181	343	NO_3	4.23	4.0	105.9
181	343	NO_3	4.27	4.0	106.9
180	343	NO_3	25.29	25.0	101.1
180	343	NO_3	25.47	25.0	101.9
182	342	SO_4	0.57	0.6	95.6
181	342	SO_4	3.82	4.0	95.6
180	342	SO_4	25.84	25.0	103.3
182	343	SO_4	0.64	0.6	106.7
182	343	SO_4	0.62	0.6	103.8
181	343	SO_4	4.10	4.0	102.6
181	343	SO_4	4.01	4.0	100.2
180	343	SO_4	25.20	25.0	100.8
180	343	SO_4	25.09	25.0	100.3

TABLE 2.4-23. Quality control data -- duplicate sample data.

CUST ID	Analysis ID	Date Analyzed	Analyte	1st Value µg/ML	2nd Value µg/ML	% Difference
WRSP 1	228	342	F	0.028	0.029	4.9
WRSP 14	241	342	F	0.021	0.021	-0.4
WRSP 1	228	343	F	0.028	0.028	0.6
WRSP 1	228	343	F	0.028	0.024	-19.7
WRSP 1	228	342	CL	0.220	0.239	8.4
WRSP 14	241	342	CL	0.023	0.024	3.5
WRSP 1	228	343	CL	0.230	0.234	1.9
WRSP 1	228	342	NO_2	0.001	0.019	103.8
WRSP 14	241	342	NO_2	0.011	0.014	20.8
WRSP 1	228	343	NO_2	0.020	0.021	6.7
WRSP 1	228	342	PO_4	-0.026	0.042	-263.8
WRSP 14	241	342	PO_4	0.029	-0.029	-198.6
WRSP 1	228	343	PO_4	0.065	0.052	-19.5
WRSP 1	228	342	BR	-0.130	-0.163	25.2
WRSP 14	241	342	BR	-0.196	-0.225	14.6
WRSP 1	228	343	BR	-0.032	-0.042	29.1
WRSP 14	241	342	NO_3	0.339	0.343	1.2
WRSP 14	241	342	NO_3	0.370	0.387	4.4
WRSP 1	228	343	NO_3	1.315	1.305	-0.7
WRSP 1	228	342	SO_4	0.988	1.011	2.3
WRSP 14	241	342	SO_4	0.662	0.660	-0.3
WRSP 1	228	343	SO_4	0.922	0.929	0.7

TABLE 2.4-24. Results of rainfall chemistry analysis.

Sample Date	Analysis ID	PM Units	COND µMHOS/CM	F µg/ML	CL µg/ML	NO_2 µg/ML	PO_4 µg/ML	BR µg/ML	NO_3 µg/ML	SO_4 µg/ML
February 9	WRSP 10	6.26	60	0.161	0.206	0.119	-0.03	-0.18	1.07	0.86
February 25 - 28	WRSP 11	5.11	13	0.035	0.068	0.009	0.08	-0.05	0.81	0.62
March 2 - 7	WRSP 14	5.01	10	0.022	0.026	0.009	0.06	-0.05	0.41	0.65
March 11 - 14	WRSP 15	5.04	14	0.019	0.090	0.010	0.05	-0.06	0.68	1.02
March 14 - 17	WRSP 13	5.12	24	0.035	0.130	0.053	0.08	-0.05	1.46	1.92
April 29 - May 2	WRSP 3	5.45	15	0.025	0.152	-0.010	-0.03	-0.14	8.09	0.95
	WRSP 20	4.70	13	0.015	0.104	-0.002	0.05	-0.06	0.69	0.69
May 16 - 18	WRSP 8	4.86	8	0.017	0.033	-0.004	0.05	-0.04	0.28	0.59
	WRSP 9	5.36	10	0.012	0.065	0.009	0.05	-0.05	0.28	0.60
	WRSP 17	4.77	10	0.019	0.037	-0.002	0.04	-0.06	0.27	0.58
May 18 - 20	WRSP 19	4.93	38	0.104	0.308	0.033	-0.03	-0.22	2.15	2.77
June 2 - 3	WRSP 12	5.52	48	0.070	0.609	-0.010	0.33	-0.18	2.44	-0.05
July 22 - 25	WRSP 1	5.22	20	0.028	0.230	0.020	0.07	-0.03	1.32	0.92
July 25 - 27	WRSP 18	5.84	-	0.038	0.407	0.189	0.06	-0.21	1.91	1.54
August 11 - 12	WRSP 5	5.03	20	0.040	0.140	0.012	0.10	-0.04	1.19	1.22
	WRSP 16	5.06	18	0.066	0.114	-0.003	0.04	-0.06	1.12	1.15
September 23	WRSP 2	4.49	36	0.190	0.258	-0.010	-0.03	-0.13	10.03	2.43
September 30 - October 3	WRSP 4	4.96	6	0.056	0.050	-0.005	0.04	-0.03	-0.04	0.32
	WRSP 6	4.92	5	0.011	0.066	-0.004	0.04	-0.04	0.24	0.33
	WRSP 7	4.84	6	0.018	0.052	-0.004	0.04	-0.04	0.13	0.32

- = Low volume.

TABLE 2.4-25. Storm air mass data.

Acid Rain Sample Days	Flow Aloft	Surface Flow	Air Mass	Comments
February 9, 1983	W	SE	Maritime	Trough
February 25-28, 1983	S-SW-W	SE	Maritime	Trough
March 2-5, 1983	S-SW	SE	Maritime	Occlusion periods of Utah polar continental outbreak
March 5-7, 1983	NW	N	Polar	Occlusion periods of Utah polar continental outbreak
March 11-14, 1983	SW	SE	Maritime	Cold front
March 14-17, 1983	W-NW	S-SE	Maritime	Cold front
April 29 - May 2, 1983	SW	S-SE	Maritime	Front
May 16-18, 1983	NW	NW	Maritime	Front
May 18-20, 1983	NW	N	Maritime	Trough
June 2-3, 1983	SW	SE	Maritime	Front
Juy 22-25, 1983	Weak SW	SE	Subtropical	Thunderstorms
July 25-27, 1983	SW	SE	Subtropical	Trough - front
August 11-12, 1983	Weak SW	SE	Subtropical	Front
September 23, 1983	SW	S-SE	Subtropical	Thunderstorms - cutoff low
September 30 - October 3, 1983	S	SE-E	Subtropical	Deep trough - front - cutoff

Mexico, usually during the winter months. The maritime air mass originated on the West Coast. The period of March 2-7 started as a maritime air mass and eventually turned into a polar air mass from Canada on March 5-7 due to the occlusion which passed south of Utah. The polar air mass occurred only once.

The chemistry data vary only slightly from sample to sample. The pH ranged from a low of 4.49 to a high of 6.26. No variation was observed between any of the ion species measured except for the NO_3^- and $SO_4^=$ concentrations of 23 September (WRSP 2), the NO_3^- concentration of 29 April - 2 May (WRSP 3), and the $SO_4^=$ concentration of 18 May - 20 May (WRSP 19) (when these ions were present in much higher concentrations than normal).

The meteorological data for 23 September (sample I.D. WRSP 2) when the highest NO_3^- was observed is shown in Table 2.4-26. An examination of the data during the period from 0900-1300 shows the relative humidity was high and the wind speed was low, creating stagnant conditions. The wind direction had reversed, coming from the north carrying pollutants into the stagnant air mass over the sample site. The correlation between the $SO_4^=$ concentration and mean ambient SO_2 concentration (Table 2.4-27) was found to be in good agreement. No NO_x data were collected during this period since the NO/NO_x analyzer was out for repair.

Similar meteorological conditions also existed for sample I.D. WRSP 19 (May 18-20), with the winds originating from the north. A good correlation between the ambient and ionic chemistry, however, could not be obtained. The NO_3^- data from WRSP 3 appear to be in error when compared with the replicate data for the same days, WRSP 20 (April 29 - May 2).

TABLE 2.4-26. Meteorological data for 23 September 1983.

Hour	Wind Speed	Wind Direction	Temperature	RH	Net Solar Radiation
0	3.0	SSW	16.5	49	-.09
1	5.2	SE	15.5	50	-.09
2	6.2	SSW	14.5	54	-1.0
3	4.3	SE	11.9	58	-1.0
4	7.7	SE	11.4	60	-1.0
5	3.8	SE	10.4	65	-0.9
6	4.4	SE	10.6	63	-0.6
7	4.1	S	14.3	62	.03
8	6.8	WSW	15.7	70	.02
9	5.5	SSW	14.6	88	.05
10	4.8	WSW	13.4	97	.00
11	2.2	NW	13.0	98	.07
12	7.5	SE	13.4	96	.19
13	12.3	SSE	15.4	87	.39
14	8.0	SSE	18.4	68	.46
15	4.0	SE	20.2	57	.20
16	6.3	SSE	20.4	53	.01
17	11.6	S	19.3	58	-.05
18	6.6	SSE	17.9	64	.07
19	7.9	S	17.3	66	.08
20	9.7	SSW	17.1	66	.08
21	5.5	S	16.9	65	.07
22	2.8	WSW	16.5	67	.07
23	4.9	SSW	16.4	68	.08

TABLE 2.4-27. Mean ambient NO_x and SO_2 ($\mu g/m^3$), during the days with precipitation.

Date	NO_x	SO_2
February 9	3	7
February 25	0	3
February 26	0	3
February 27	0	3
February 28	0	3
March 2	0	0
March 3	0	0
March 4	0	0
March 5	0	0
March 6	0	0
March 7	0	0
March 11	-	0
March 12	-	0
March 13	-	0
March 14	-	0
March 15	-	0
March 16	-	0
March 17	-	0
April 29	0	0
April 30	0	0
May 1	1	0
May 2	1	0
May 16	1	0
May 17	2	0
May 18	0	0
May 19	0	0
May 20	0	1
June 2	0	0
June 3	0	0
July 22	0	0
July 23	0	1
July 24	0	2
July 25	0	2
July 26	0	2
July 27	0	2
August 11	0	4
August 12	0	5
September 23	-	6
September 30	-	6
October 1	-	5
October 2	-	5
October 3	-	5

- = No data collected.

E. Conclusion It should be emphasized here that the ionic concentrations measured are very low; they averaged about 0.2 mg/ml, and usually below the lower detection limit (negative data) of the ionic analyzer. However, examining general trends and outliers, it can be concluded from this limited experiment that the rainfall is basically neutral with little contributions from transport. High ionic species concentrations relative to the overall results appeared in those instances in which a stagnant meteorological condition was created. Local sources appeared to be the contributing factors.

These results are in agreement with those obtained by Tombach and Pettus (1982). Tombach and Pettus examined the spatial variability of precipitation chemistry in the Los Angeles Basin and found that, as the storms monitored traveled farther inland, the pH chemistry and ionic species tended to decrease. Higher $SO_4^=$ and NO_3^- concentrations were observed in those instances in which there were local source contributions.

2.4.4.2 Low-Level Temperature Relationships Temperature measurements made at several locations throughout the tract were summarized in Section 2.4.2.2. These measurements were made at 10 or 30 m above the ground, as is typical for an air quality measurement program. However, temperatures in the "life zone" or first 2 m are also important from an ecological standpoint. For the White River Shale Project, temperature inputs for the very lowest levels (<2 m) are needed primarily to determine if revegetation plans for disturbed areas and the retorted shale disposal pile are viable.

As a prelude to doing any measurements of this type, the literature on this subject was reviewed to determine if temperatures measured at 10 m could be extrapolated to the life zone with any degree of certainty. While most studies investigated temperature relationships for specific surfaces and various height ranges, some conclusions can be drawn:

- Temperature distribution in the surface boundary layer is the most complicated in the atmosphere (Matveev, 1965).
- Temperature profiles in the lowest 10 m are affected by surface properties, including composition, color, vegetation and angle with respect to the sun (Munn, 1966; Terjung and O'Rourke, 1982; Murro and Davis, 1978; Lettau, 1979).
- Temperature profiles in the lowest 10 m are also affected by origin, temperature, latent heat content, and relative motion of the air over the surface (Vugts and Businger, 1977; Bill, et al, 1979; Desjardins, et al, 1978).
- Temperature lapse rates in low levels range from superadiabatic (>50°C/100 m) to isothermal (Geiger, 1965; Baxter, 1977).

In relating these findings to the WRSP, the darker color of the retorted shale would undoubtedly change the reflective properties of the surface. The dark color would contribute to hotter daytime surface temperatures and cooler nighttime temperatures, making the temperature profile over the pile more extreme. Establishing vegetation on the retorted shale should moderate this effect, although the arid climate in this area would keep vegetative cover fairly sparse.

In conclusion, a quantitative relationship of temperatures in the low levels can best be defined by direct measurement at the level and over the surface type required.

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VEGETATION RESOURCES

3.0 VEGETATION RESOURCES

3.1 INTRODUCTION

The following section discusses the vegetation monitoring studies conducted during 1983 by NPI (Native Plants, Inc.) under contract to WRSOC. The vegetation monitoring program under the direction of Dr. Cyrus McKell incorporates data from the 1974-1976 baseline studies with the data collected on Tracts Ua and Ub since that time. There has been a concerted effort to document existing conditions and determine interactions between the vegetation and abiotic and biotic factors on the tracts. The vegetation monitoring program affords two important advantages:

- documentation of vegetation responses to natural fluctuation or variation, that could otherwise be interpreted as impacts of development; and
- identification of problems early before they become serious, enabling corrective measures or contingencies to be initiated prior to any irreversible environmental change.

The vegetation monitoring program is also designed to provide data that describe the possible effects on the vegetation community caused by oil shale mining, processing and disposal of the retorted shale. The array of vegetation-related parameters used in monitoring includes key vegetation-related characteristics that are vital to ecosystem function. The characteristics are sensitive to immediate impacts of development or to cumulative influences plus interactions with affected ecosystem processes. The monitoring program includes variables that are indicative of environmental health and responsive to environmental impact.

3.2 SUMMARY

The vegetation monitoring program was composed of nine interrelated tasks that are designed to document existing conditions, determine and quantify interaction between the vegetation and abiotic and biotic factors, and provide a means of identification of impacts on the vegetation by development. A summary of the results for 1983 for each of those nine components follows.

3.2.1 Production of Annual Plant Biomass

Production of annual plant biomass was very high in 1983 with the total of all four community types averaging 64.6 oven-dried g/m^2. This was lower than only 1975, which had 217.3 g/m^2. The riparian vegetation type again had the highest biomass and cover of the four vegetation types considered averaging 116.4 g/m^2 and 14.9%, respectively. The juniper type had the lowest biomass and cover averaging, 1.2 g/m^2 and 0.4%, respectively. The shadscale type averaged 61.5 g/m^2 for production and 10.2% for cover, while the sagebrush-greasewood areas averaged 79.2 g/m^2 for production and 11.3% cover. Precipitation records were compared with annual plant biomass data and production is highly correlated with January, April, and May precipitation. The winter months represent a period of soil water recharge; this, combined with April and May data, appear to be an excellent indicator of annual species success.

3.2.2 Sagebrush Leader Growth

Over the nine years of study, sagebrush stem growth ranged from 2.7 cm in 1977 to a high of 8.4 cm in 1979. The data for 1983 on sagebrush leader growth (7.4 cm) was the third highest value recorded during this time period. An analysis of variance (ANOVA) was performed on the data (Sites 1-6) for the nine

years of record. The results point out that there was a significant difference between years. An ANOVA test comparing study sites on tract also showed significant differences. Site 3 had significantly longer stem lengths than any of the other sites.

Growing conditions for sagebrush in 1983 were very good and this was reflected in the increased stem lengths. The variability of stem length is highly correlated with (December, January, and March) precipitation. The precipitation for the winter period averaged 10.73 cm which was the second highest average recorded (1979 was highest with 10.85 cm).

3.2.3 Plant Chemical Composition

Sagebrush leaders from the seven sagebrush stem growth sites were analyzed for molybdenum, arsenic, sodium, calcium, magnesium, sulfates, mercury, cadmium, and boron. These parameters were selected because they have the potential to accumulate in plant tissue as a result of industrial development. Values obtained from the analyses all show levels within the normal range of concentrations within plants. These values will serve as baseline data for later comparisons after the processing plant is in operation.

3.2.4 Litterfall Measurements

A total of 242 litter traps were placed underneath seven dominant species of shrubs and trees, at locations scattered throughout the tracts to assess the amount of biomass returning to soil. The data on litterfall will serve as baseline in assessing the health and vigor of the dominant species in the area as well as providing information on nutrients returning to the soil and food resources to many small animals. Litterfall was highest (on a weight per size

index or volume) for shadscale at 174 g/m^3. Sagebrush averaged 118.5 g/m^3, followed by spiny hopsage (74.9 g/m^3), greasewood (40.5 g/m^3), rabbitbrush (39.5 g/m^3) and finally, fourwing saltbush (38.4 g/m^3). Juniper litter traps were not equivalent to those traps used for the six shrub species and should not be compared with litterfall from these species. Litterfall under juniper did decrease in 1983 (54 g/m^2) from 1981 (123 g/m^2) and 1982 (112 g/m^2) levels for the June to October sampling period.

3.2.5 Assessment of Animal Utilization of Plants

Animal use of shrubs was assessed using the Cole Browse Survey at six sites utilizing three key forage species. June 1983 data showed that sagebrush leader growth was browsed (4%) less than shadscale (41%) and greasewood (17%). In addition to the Cole Browse Survey Method to assess browse useage, 20 sagebrush plants were enclosed with chicken wire in October 1982 and in April 1983 caged and noncaged leader length were measured to obtain estimates of actual biomass taken by browsing animals. Results showed no significant difference between caged and uncaged shrubs indicating minimal browsing of sagebrush during this period.

3.2.6 Lichen Monitoring

During the 1982 field season, 21 permanent stands were located along three transects radiating from the proposed plant site. At each stand a permanent photo plot was established and a 20 m transect was permanently marked from which cover and frequency data were taken. The plots were revisited in 1983, photographs were taken to document baseline conditions, total lichen cover was estimated and the frequency of each species recorded.

Parameters found to be good indicators of current conditions and valuable for monitoring future impacts include total cryptogamic cover, number of species/quadrat and frequency of eight key lichen species. The variability of the other parameters measured negated their use in a monitoring program such as the one designed for the White River Shale Project.

3.2.7 Plant Condition and Stress

Aerial Color Infrared (CIR) photographs were taken along three transects traversing the proposed plant site to determine the optimum scale for detecting plant stress. Photographs were taken at only one scale (1:2400) since 1982 data showed this scale to be more effective for monitoring vegetation stress on and near to the tracts. If a more dense vegetation was present, the photographs taken at 1:6000 would be advantageous in showing overall vegetation stress.

Through ground reconnaissance in 1982, stressed vegetation was marked on the photographs and where possible, the causal agent noted. The stressed plants were categorized into two major groups; those resulting from a phenological stage and those showing causal agents, such as disease or mechanical disturbance. The emphasis of the 1983 plant stress study was to quantify the data for both 1982 and 1983. The quantified data from the two years were compared. Only minor differences were found between the two years and those were due to photography resolution and not additional stressed areas.

3.2.8 Soil Microbiology and Soil Chemistry

Samples were taken along transects at eight sites within the four vegetation types recognized on the tracts. The sites were sampled quarterly (January, April, July, October) in 1983 to assess yearly fluctuations. Soil

moisture content fluctuated from a high in January of 21.5% to a July low of 1.1%. Moisture levels were 1-2% higher in subsurface soils during summer months while the moisture levels of the surface soils are 5-10% higher during the winter. This yearly fluctuation and soil sample patterns were similar to results in 1981 and 1982, although the April values in 1983 were almost twice that of 1981 or 1982. Soil pH, organic carbon, and EC levels did not change significantly through the year. They also showed little differences between sites. EC levels did show a sharp increase in the July sample from the 1981 or 1982 analysis. pH and organic carbon readings for 1983 were very similar to 1981-1982 data.

Soil bacteria fluctuated in an annual cycle characterized by a sharp winter high and a summer low. Bacterial counts were $\pm$ 50% lower in subsurface soils (5-15 cm) than surface soils (0-5 cm). Fungal populations which showed a general decline through 1982 increased sharply in April 1983 to roughly June 1981 levels, but then decreased in October to the lowest levels yet recorded on site.

Respiration rates showed an annual cycle that corresponds to the bacteria counts with winter high (9.0 meq $CO_2 \times 10^{-4}/g \cdot hr$) and a summer low (2.1 meq $CO_2 \times 10^{-4}/g \cdot hr$). Surface and subsurface samples were not significantly different. Dehydrogenase activity exhibited nearly a 6-month cycle with high in January and July and low in April and October. This corresponds to data from 1981-1982.

Correlations between chemical microbiologic factors identified two major relationships:

(1) High bacterial counts, total fungi, dehydrogenase, and microbial respiration levels were associated with relatively moist soils.

(2) Bacterial numbers and activities tend to be positively correlated with organic-matter.

The correlation coefficients are generally low (0.2-0.5) for most analyses, but the relationships do represent logical patterns and will serve as valuable baseline information.

3.2.9 Revegetation Success on Disturbed Sites

Revegetation efforts along new roads within the plant site began in the fall of 1982 and continued in 1983. Areas paralleling the roads were seeded using both hydromulching and drill seeding, and in certain locations transplants were used to revegetate the barren slopes. In June of 1983, four sites were located between Duck Rock and the Security Station at the plant site. The sites were sampled twice during 1983 to evaluate success. The initial sampling occurred June 6-8, 1983. This sample information was used to assess the revegetation success using a stand rating system described in Vallentine (1974). Survival of transplanted shrubs was also recorded. Initial seeding and transplant survival for the June sampling was excellent.

The same sites were resampled in October to determine the survival after the critical summer period. The average density of all plots on all sites was 9.6 plants/m^2 which would be classified by Vallentine (1974) in the excellent category for seeding success in the Intermountain area. Of the 12 plots sampled, however, four plots would fall into the excellent category, four into the good category and four into the fair category. The commonly encountered

species were sagebrush averaging approximately 4 plants/m^2, followed by western wheatgrass (3 plants/m^2) and fourwing saltbush (1 plant/m^2).

An initial survey of survival of transplants in June 1983 showed that 83% of the plants were alive at Site 3. Sagebrush had the best survival (96%) and rabbitbrush had the poorest (50%). A transect in the same area in October showed that significant losses had occurred. The survival of sagebrush had decreased to 36% while no living transplants of fourwing saltbush, rabbitbrush, or shadscale were found. This low survival figure is primarily due to the high herbivore population, as described in Chapter 5, Terrestrial Fauna.

3.3 PROGRAM DESCRIPTION

3.3.1 Objectives

The three main objectives of the vegetation program are:

- To document the existing vegetation conditions during and after various stages of development, including the range of variation exhibited temporally and geographically.
- To quantify plant responses to environmental impacts created by development, thereby allowing comparisons of plant responses in areas of little or no impact with those in areas of relatively high impact.
- To measure the success of revegetation techniques on the processed shale disposal area and other areas that may be disturbed during operations.

The first revegetation activities occurred in 1982 and continued into 1983. The initial disturbance was associated with construction of the new road to the plant site. Monitoring was initiated in 1983 on this area for plant establishment and revegetation success. The area of greatest impact to the vegetation in terms of area disturbed, however, will be the processed shale pile. Revegetation techniques for processed shale are still being investigated and are discussed in Chapter 7. Many of the parameters discussed below will be used in monitoring the processed shale area, however, it is anticipated that other parameters may be identified from the special revegetation studies that could be added to the vegetation monitoring program at a later date.

3.3.2 Site Locations

The vegetation resources program continued to use the areas of sampling established in the 1974-1976 baseline work and those areas initiated during 1981

by the addition of several new studies. The locations of all the study sites are shown in Figure 3.3-1. The actual overflights for detecting plant conditions and stress were extended so that the proposed plant site represents the center of each transect and the transects will better correspond to predicted effluent patterns. Details for the selection of the sites are discussed fully in the WRSP Environmental Monitoring Manual (1982).

3.3.3 Methods

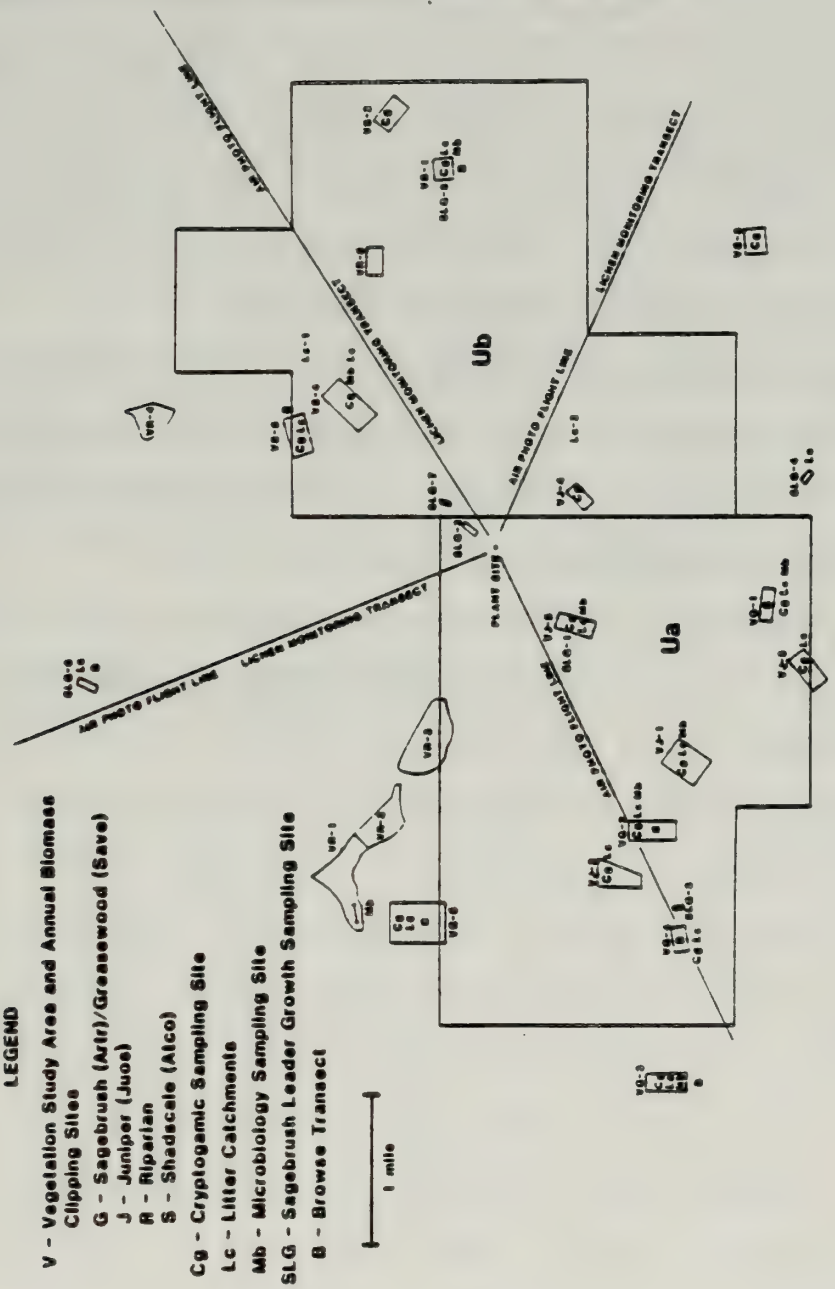
The methods used during the 1983 program are essentially the same as those utilized during the previous years of study. The WRSP Environmental Monitoring Manual (EMM) contains a detailed description of the methods employed and the schedule for sampling. Deviations from the EMM occur primarily when sample sizes are adjusted to provide for more statistically valid data or when field conditions necessitate a change. Any such changes are described in the appropriate section of this report.

3.3.4 QA/QC Program

The Quality Assurance and Quality Control program described in the EMM was initiated during the 1982 program and continued in 1983. The field and laboratory data collection has been verified and thoroughly documented. All pertinent data, both raw and summarized, have been placed onto computer tapes under the direction of WRSOC and according to the format specified. Duplicate tapes were made for the Oil Shale Projects Office and for WRSOC files. Original data sheets are being kept in NPI files.

Soils analysis was the area for most concern in the QA/QC program. To assure quality, duplicate samples were analyzed on selected soils. Also, soils

Figure 3.3-1. Location of Vegetation Resources Study Areas.



were analyzed by only certified labs. Sample handling is important in the soil microbiology samples, since heat and time will create an incubation of the organisms (bacteria and fungi) and artificially increase their numbers. This is what occurred with the 1981 samples. The samples are currently being cooled within a few minutes of being taken and kept in cold storage (walk-in refrigerator) until analysis. Analysis begins as soon as the soils are received in the lab also to reduce any incubation time.

Soil analysis methods are standardized, yet, there is often considerable variation when analyzing for particular elements. This suggests that the variability is in the soil matrix and care must be taken in deriving conclusions about differences in elements with high variability.

Aerial Photographic products were also an area of concern and these were carefully monitored. Each frame has the altitude, time and date printed directly on them.

3.4 PROGRAM RESULTS AND ANALYSIS

Eight separate components are included in the vegetation monitoring program in the EMM. Three of these are identified as operational parameters, production of annual plant biomass, sagebrush stem growth, and soil chemistry. These will probably be continuously monitored. Four components are listed as potential parameters including, lichen growth, litterfall, plant conditions and stress and soil microbiology. One final component is listed as a contingency parameter and that is plant chemical composition. Along with this there are portions of the soil chemistry and soil microbiology parameters that will be included as contingency parameters. The results of each of these components along with the revegetation success component, are reported in the following sections.

3.4.1 Production of Annual Plant Biomass

In June 1983, five productivity study areas were visited in each of the four major vegetation types identified during the baseline program (Refer to Figure 3.3-1 for the locations). In each study area, plant cover was recorded and above-ground annual plant biomass was harvested from twenty 0.25 m^2 plots. Plants were clipped at ground level, and returned to the lab for weighing. Oven dried weights were reported previously for each study site, as well as, cover percentages (NPI Second Quarter Report, 1983).

Previous analyses have shown that annual species biomass is related to spring precipitation. Precipitation records for the water year 1982-83 showed that the winter and spring months were generally above normal (refer to Chapter 6, Water Resources). Multiple regression analysis of the 1975-83 data for

annual plant biomass and monthly precipitation shows that January, April, and May precipitation are significantly correlated with annual biomass. Precipitation in the other months add little if any strength to the regression (Figure 3.4-1).

Comparisons of 1983 annual biomass data with the preceding years are shown in Table 3.4-1. In comparisons of biomass averages of all four vegetation types for the nine years of record, 1983 ranked second highest in maximum biomass and was about 200% greater than biomass production in 1982. The upswing in rodent and rabbit populations took advantage of this additional and important source of herbage and seeds.

The riparian vegetation type again had the largest values for production and cover of the four vegetation types considered, averaging 116.4 gm/m^2 and 14.9%, respectively. The juniper type had the lowest figures averaging 1.2 gm/m^2 for production and 0.4% for cover. Production values for individual vegetation types are discussed below.

3.4.1.1 Shadscale Vegetation Type Annual species biomass was the second highest ($\bar{X}$ = 61.5 gm/m^2) of the nine years of record for this vegetation type in 1983. Cheatgrass was again the dominant annual species on this vegetation type and it occurred most frequently in protected areas underneath shrubs. Cover estimates averaged 10.2% with a range from 3% to 25%.

3.4.1.2 Sagebrush - Greasewood Vegetation Type Annual species production in the sagebrush - greasewood areas averaged 79.2 gm/m^2. This total is the highest biomass yield to date. The general pattern of plant distribution was similar to the shadscale type with most of the production occurring underneath

Figure 3.4-1. Regression analysis of precipitation (January, April, May) with Annual Species Biomass.

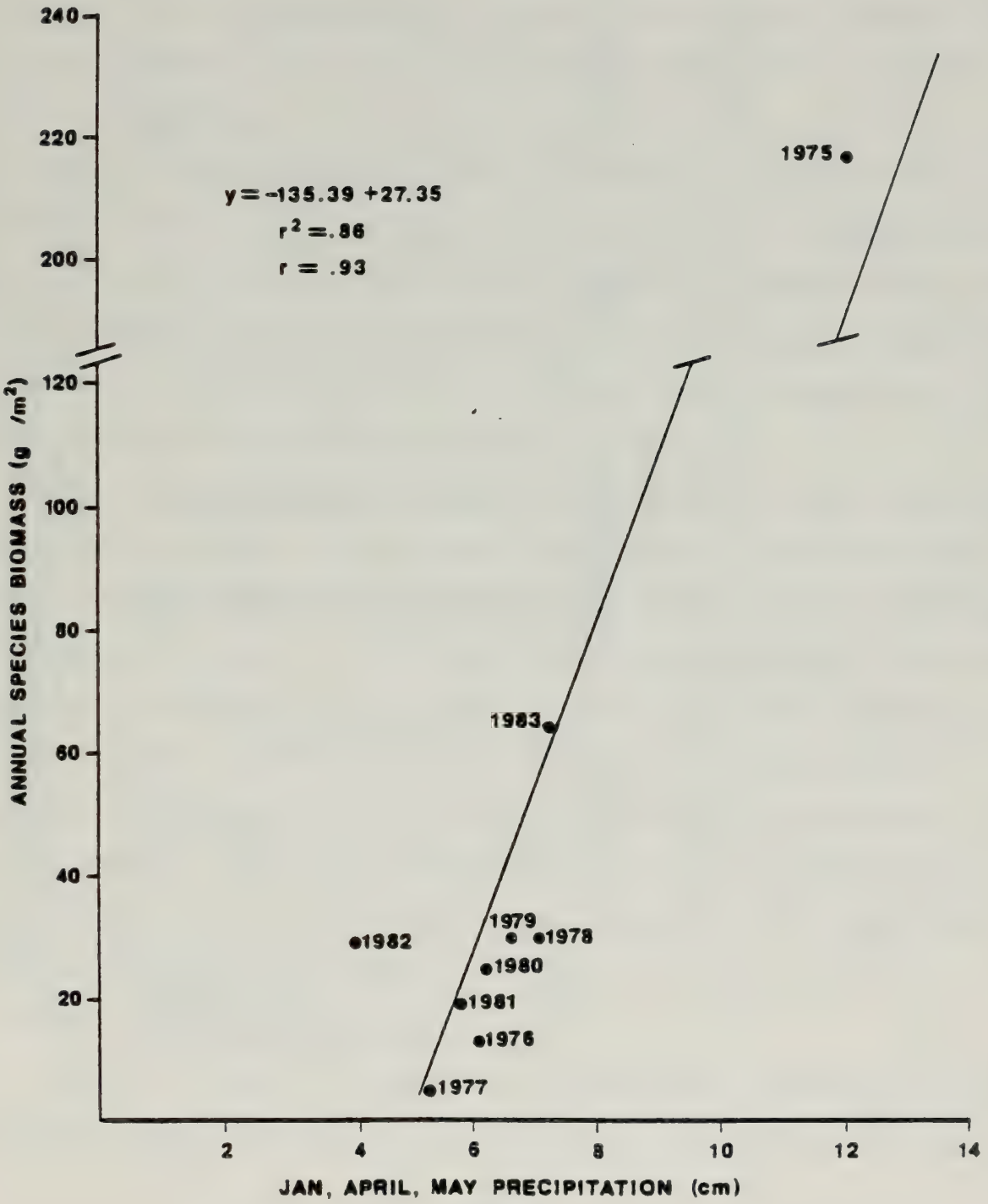


Table 3.4-1. Biomass production of annual understory vegetation of four primary vegetation types during 1983 and compared with previous years.

Sample Location (1)	VEGETATION TYPE: Shadscale Production (g/m^2)	Shadscale Plant Cover (%)	Sagebrush-Greasewood Production (g/m^2)	Sagebrush-Greasewood Plant Cover (%)	Juniper Production (g/m^2)	Juniper Plant Cover (%)	Riparian Production (g/m^2)	Riparian Plant Cover (%)
1	76.4	9.1	22.8	2.3	1.2	0.3	95.6	13.0
2	100.0	25.0	20.4	2.5	1.2	0.5	221.6	26.8
3	55.6	7.0	302.8	47.0	1.6	0.4	231.2	29.7
4	20.8	3.1	27.6	2.1	1.2	0.3	12.4	1.9
5	54.8	7.0	22.0	2.7	1.2	0.3	20.4	2.9
1983 Avg.	61.5	10.2	79.2	11.3	1.2	0.4	116.4	14.9
1982 Avg.	24.7	6.4	21.4	5.5	0.4	0.2	68.1	18.2
1981 Avg.	9.2	3.4	15.8	4.8	0.6	0.2	51.5	17.4
1980 Avg.	21.8	2.3	8.9	0.9	0.5	trace	(3)	(3)
1979 Avg.	16.5		16.9		6.3		82.5	
1978 Avg.	5.4		35.1		1.6		80.0	
1977 Avg.	0.0(2)		0.0(2)		0.0(2)		20.6	
1976 Avg.	3.8		20.9		0.3		30.6	
1975 Avg.	224.3		51.1		3.8		590.0	

(1) Each value is a mean of 20 plots within areas sampled during and since the Baseline.
(2) Vegetation was not sampled (too meager to harvest).
(3) Biomass sampling data unavailable because of sample handling problems.

the shrubs. Areas between shrubs had a sparcer cover. Besides cheatgrass, an annual Cryptantha sp. and pepperweed (Lepidium perfoliatum) were occasionally found within this vegetation type. Cover values for the annual species were much higher than all other years with an average cover value of 11.3% and a range of 2.1 to 47%.

3.4.1.3 Juniper Vegetation Type The production of annual species in this vegetation type was low as is typical with the juniper zone. Average production was only 1.2 gm/m^2 compared with 0.4 gm/m^2 in 1982. The dominant annual species in this type was cheatgrass with some lambs' quarters (Chenopodium album) and pepperweed. The total cover in the juniper sites sampled averaged 0.4% cover which is double that for 1981 or 1982 data.

3.4.1.4 Riparian Vegetation Type As in all previous years, the riparian vegetation type produced the most annual plant biomass. Again, the dominant species was cheatgrass, with a fair abundance of yellow sweetcover (Melilotus officinalis), pepperweed, and fat hen saltbush (Atriplex patula). The grazing pressure on the riparian areas is more severe than on the other vegetation types and much of this disturbance leads to an increase in the preponderance of annuals. These annuals may in turn serve as a source of food for animals during a short period in the spring. The production of annuals for 1983 averaged 116.4 gm/m^2. Average cover values for the riparian vegetation sites ranged from 2% to 30% with an average cover of 15%.

3.4.2 Sagebrush Leader Growth

There was no change in methodology used for sampling sagebrush (Artemisia tridentata) stem growth measurements during 1983. The annual growth of 20 stems

Table 3.4-1. Biomass production of annual understory vegetation of four primary vegetation types during 1983 and compared with previous years.

Sample Location (1)	VEGETATION TYPE: Shadscale Production (g/m^2)	Shadscale Plant Cover (%)	Sagebrush-Greasewood Production (g/m^2)	Sagebrush-Greasewood Plant Cover (%)	Juniper Production (g/m^2)	Juniper Plant Cover (%)	Riparian Production (g/m^2)	Riparian Plant Cover (%)
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1980 Avg.	21.8	2.3	8.9	0.9	0.5	trace	(3)	(3)
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1977 Avg.	0.0(2)		0.0(2)		0.0(2)		20.6	
1976 Avg.	3.8		20.9		0.3		30.6	
1975 Avg.	224.3		51.1		3.8		590.0	

(1) Each value is a mean of 20 plots within areas sampled during and since the Baseline.
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3.4.1.4 Riparian Vegetation Type As in all previous years, the riparian vegetation type produced the most annual plant biomass. Again, the dominant species was cheatgrass, with a fair abundance of yellow sweetcover (Melilotus officinalis), pepperweed, and fat hen saltbush (Atriplex patula). The grazing pressure on the riparian areas is more severe than on the other vegetation types and much of this disturbance leads to an increase in the preponderance of annuals. These annuals may in turn serve as a source of food for animals during a short period in the spring. The production of annuals for 1983 averaged 116.4 gm/m^2. Average cover values for the riparian vegetation sites ranged from 2% to 30% with an average cover of 15%.

3.4.2 Sagebrush Leader Growth

There was no change in methodology used for sampling sagebrush (Artemisia tridentata) stem growth measurements during 1983. The annual growth of 20 stems

on each of 20 separate plants in each of seven sampling locations (2800 samples total) was measured. Locations of the sampling sites are shown in Figure 3.3-1. Each measurement was from the bud-scale scar of the previous year to the tip of the new growth. This marks the ninth year that this data has been collected on sites SLG-1 through SLG-6 and the third year of data for site SLG-7. Results of each site for 1983 were reported in Tables 1-7 of the third quarter report and only summaries will be reported here.

Growing conditions for sagebrush in 1983 were good for stem growth, and this is generally reflected in the stem lengths. The variability of stem length is highly correlated with winter precipitation (Figure 3.4-2). The precipitation for the winter period for 1983 averaged 10.7 cm which was the second highest average recorded. Stem length was slightly below the value that would be predicted strictly by the regression equation but it was still well within the 90% prediction interval (Figure 3.4-3).

Average stem length ranged from 4.6 cm at site 5 on the east edge of tract Ub to 9.4 cm at site 6 which is north of tract Ua (Table 3.4-2). The standard deviations for all seven sites are quite uniform which illustrates that the variability of stem growth is low.

Over the nine years of study, average sagebrush stem growth ranged from 2.7 cm in 1977 to a high of 8.4 cm in 1979 (Table 3.4-2). The data for 1983 on sagebrush leader growth (7.4 cm) was the third highest value recorded during this time period. An analysis of variance (ANOVA) was performed on the data (sites 1-6) for the nine years of record. The results, shown in Table 3.4-3, point out that there was significant difference between years. The results of

Figure 3.4-2. Graph of sagebrush stem growth and winter precipitation.

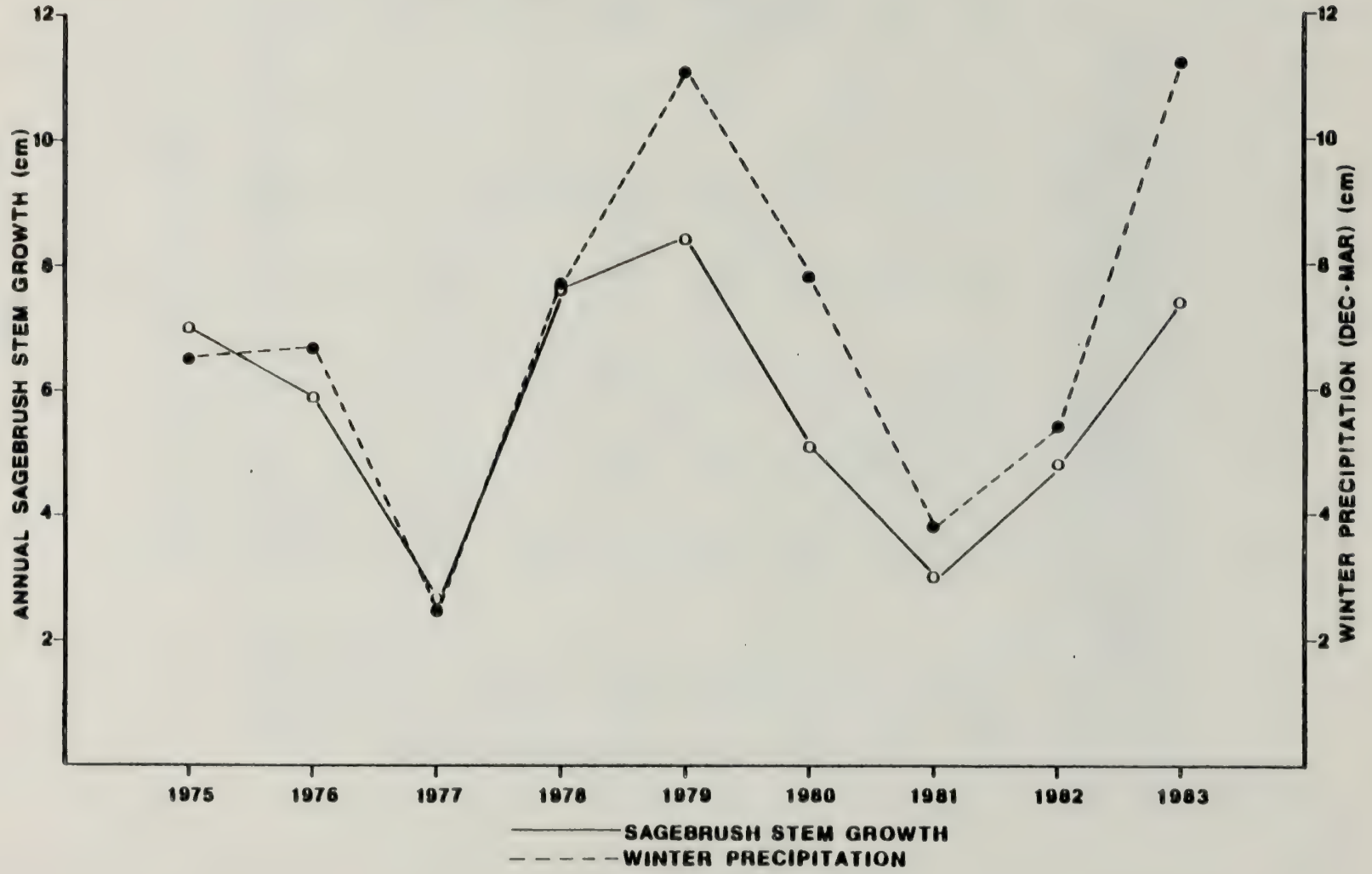


Figure 3.4- 3. Regression of sagebrush stem growth and winter precipitation. The dashed lines represent the 90% prediction level.

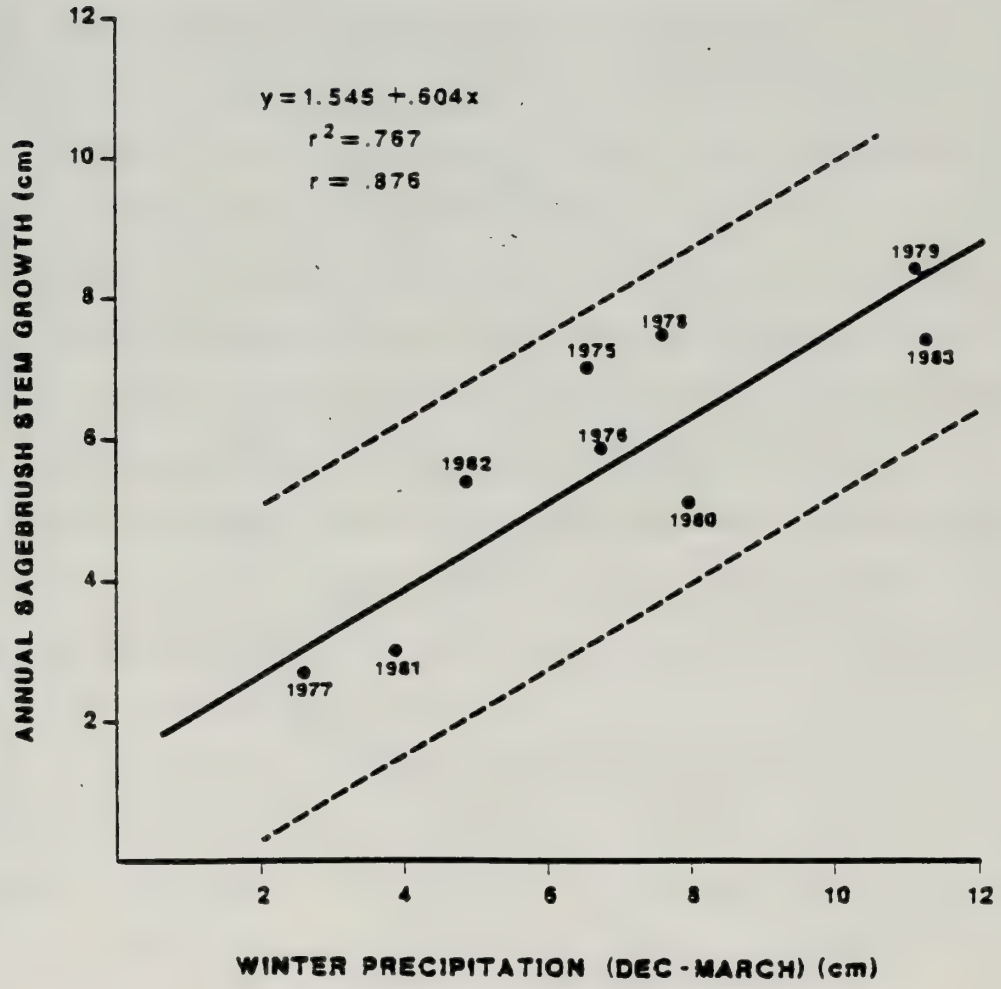


Table 3.4-2. A comparison of sagebrush stem growth over a nine year period, 1975 to 1983 on sites related to prototype oil shale tracts Ua and Ub. Each value is the mean length of 20 stems on 20 plants (i.e., 400 observations/site/year). Values are expressed in centimeters. Averages followed by a common letter are not significantly different as analyzed by ANOVA and LSD mean separation tests with $\alpha \leq .05$.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Average
1975								
Mean	7.4	6.9	9.7	5.6	7.1	5.4		7.0[d]
SD	2.1	1.1	1.4	1.0	1.3	1.5		
1976								
Mean	6.2	6.2	7.0	5.5	5.4	4.8		5.9[c]
SD	1.0	1.6	0.9	1.	1.2	1.1		
1977								
Mean	2.1	2.0	4.0	2.2	2.8	2.8		2.7[a]
SD	0.4	0.3	1.0	0.3	0.5	0.6		
1978								
Mean	8.4	8.1	10.1	6.4	5.6	6.5		7.5[d]
SD	1.3	2.9	2.2	1.1	1.6	2.5		
1979								
Mean	7.6	9.9	9.9	8.2	7.3	7.7		8.4[e]
SD	2.0	2.2	2.5	2.1	1.8	1.9		
1980								
Mean	4.6	6.4	7.5	4.8	3.9	3.6		5.1[bc]
SD	1.4	1.9	1.7	1.3	1.1	1.0		
1981								
Mean	2.8	3.3	3.1	2.8	2.2	2.8	3.9	3.0[a]
SD	0.8	0.7	0.6	0.5	0.5	0.5	0.8	
1982								
Mean	4.5	5.2	5.9	4.8	3.0	4.8	5.5	4.8[b]
SD	1.2	1.4	1.1	1.1	0.6	1.5	1.2	
1983								
Mean	7.1	7.9	8.1	7.4	4.6	9.4	8.5	7.4[d]
SD	1.8	3.0	1.8	2.4	0.8	2.3	2.7	
AVG.	5.6[b]	6.2[bc]	7.3[c]	5.3[ab]	4.7[a]	5.3[ab]		

Table 3.4-3. Two-Way Analysis of Variance test of sagebrush stem growth for 1975 through 1983.

	SS	df	M.S.	F-ratio
Years	205.85	8	25.73	33.06
Sites	36.75	5	7.35	9.44*
Error	31.13	40	.78	
Total	273.73	53		

*significant at $\alpha = .01$.

the LSD mean separation test are shown in Table 3.4-2. An ANOVA test comparing sites also showed significant differences. Site 3 had significantly longer stem lengths than any of the other sites (except Site 2). The results of the LSD test are also shown in tables 3.4-2. Sagebrush leader growth appears to provide a realistic index of the year-to-year variability that occurs within the oil shale tracts and provides a good monitoring device to estimate plant variability within the ecosystem. However, the relationship does not take into account all the variability in the system. Thus, the 90% predictive level will be used to identify outlier values that may occur in future years.

In addition to the leader growth measurements for sagebrush, measurements for three other species, fourwing saltbush (Atriplex canescens), rabbitbrush (Chrysothamnus greenii), and greasewood (Sarcobatus vermiculatus) were sampled in 1983 as a comparison for sagebrush. Rabbitbrush and greasewood were sampled from Site 7 only while fourwing saltbush was sampled from LC-1 since sampling at Site 7 would involve clipping plants that were clipped in 1982 due to the low number of fourwing saltbush at that site. One hundred samples were taken for each species. These results were reported in the third quarter report and are compared in Table 3.4-4. Average leader growth was 24.5 cm $\pm$ 3.8 for fourwing saltbush, 22.7 cm $\pm$ 3.3 for rabbitbrush, and 18.1 cm $\pm$ 2.4 for greasewood. The averages for all three species are higher than the averages for sagebrush (2-3 times). Comparisons of the 1981-83 data showed that 1983 averages were higher for every species. Saltbush increased by 42%, rabbitbrush by 54%, sagebrush by 55%, and greasewood by 132%. Thus, sagebrush which increased by 55% from 1982 to 1983 at Site 7 appears, at least initially, to represent accurately the

Table 3.4-4. Average leader growth measurements (cm) of fourwing saltbush, greasewood, rabbitbrush, and sagebrush from Site 7, October 7 1983, and comparisons for 1981 - 1983.

	ATCA		SAVE		CHGR		ARTR	
	$\bar{x}$	S.D	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
1981	14.0	6.3	3.3	1.9			3.9	0.8
1982	17.3	9.9	7.8	3.3	14.7	6.6	5.5	1.2
1983	24.5	3.8	18.1	2.4	22.7	3.3	8.5	2.7

fluctuations of other shrubs to environmental change. These species will be monitored again in 1984 to further document their yearly responses to changes. This will continue to provide information as to the suitability of sagebrush as a measure of general plant resources on oil shale tracts Ua and Ub.

3.4.3 Plant Chemical Composition

Sagebrush leaders from the seven sagebrush leader growth sites were analyzed for elemental content of several potentially harmful compounds. The parameters were analyzed to establish baseline measures for future comparisons to assess effects of processing operations. Nine parameters (Mo, As, Na, Ca, Mg, SO_4, Hg, Cd, and B) were analyzed from the sagebrush tissue. The parameters were selected because they may be present in quantities greater than normally encountered as a result of industrial development associated with oil shale (Stollenwerk and Runnells, 1981) and may accumulate to levels deleterious to plants or their consumers (Kilkelly and Lindsay, 1979; OTA, 1980).

Values reported from the analyses performed in 1983 are compared with 1981-1982 data in Table 3.4-5. The values shown represent composite samples of 12 leaders per site. All of the values obtained thus far are within the normal range of concentrations within plants as reported by Gough et al. (1979).

3.4.4 Litterfall Measurements

Litterfall is being measured under the canopy of the dominant shrubs and juniper trees on the tracts. Measurements of litterfall are important because excessive litterfall of leaves and twigs from shrubs and juniper may indicate undue stress of plants. Excess litterfall and reduced leaf retention has been observed in areas of high air pollution (Taylor, 1974; Miller, 1975; National

Table 3.4-5. Comparisons of 1981, 1982, 1983 elemental analysis of sagebrush leaders collected from seven sagebrush leader growth sites. Values followed by common letters are not significantly different as tested by ANOVA and LSD ($F \leq .01, \alpha \leq .05$).

Site		Na (%)			Ca (%)			Mg (ppm)			Mo (ppm)			Cd (ppm)		
		1981	1982	1983	1981	1982	1983	1981	1982	1983	1981	1982	1983	1981	1982	1983
SLG	1	.275	.115	.088	490	.543	.463	870	901	900	.83		1.70	12.5	<1.3	8.60
	2	.486	.103	.092	445	.533	.501	930	960	1080	.70		0.90	14.8	<1.3	0.38
	3	535	.086	.114	430	.507	.508	760	973	1000	1.00		1.30	4.0	<1.3	0.27
	4	.490	.056	.052	450	.526	.426	850	992	950	.63		1.00	1.7	<1.3	2.00
	5	.305	.159	.152	445	.491	.437	930	1198	1030	.35		0.85	1.1	<1.3	0.75
	6	.305	.119	.168	405	.594	.496	790	942	849	.50		0.84	1.0	<1.3	0.45
	7	.296	.077	.083	430	.477	.522	760	906	980	.63		1.30	1.0	<1.3	1.20
X		.389[a]	.102[b]	.107[b]	442[a]	.524[c]	.479[b]	841[a]	982[b]	969[b]	.66[a]		1.13[b]	5.2[a]	<1.3[a]	1.95[a]
S.D.		.110	.033	.041	026	.039	.037	74	101	81	.21		.32	5.9		2.99

Site		As (ppm)			B (ppm)			Hg (ppb)			SO_4 (%)		
		1981	1982	1983	1981	1982	1983	1981	1982	1983	1981	1982	1983
SLG	1	0.3		<0.1	40	14	33	15		<10	.81	.13	<.01
	2	0.4		<0.1	26	11	11	9		<10	.23	.08	<.01
	3	0.2		<0.1	19	16	22	2		<10	.17	.10	.08
	4	0.3		<0.1	22	9	30	30		30	.23	.27	.02
	5	0.4		0.4	22	13	24	18		97	.21	.10	.06
	6	0.4		<0.1	25	15	13	7		<19	.19	.07	.06
	7	0.2		<0.1	25	15	26	25		26	.22	.03	.07
X		0.3[a]		< .1[b]	26[a]	13[b]	23[a]	15[a]		<28[a]	.20[a]	.11[b]	.04[c]
S.D.		0.09		.11	6.8	2.5	8.2	10		32	.02	.08	.03

Academy of Science, 1977; Miller and Elderman, 1977). Litterfall is also essential to the normal functioning of many soil parameters including nutrient cycling, and as a food source for many small animals. The area around shrubs where the litter accumulates is the nutritional "storehouse" for arid plant communities (Garcia-Moya and McKell, 1970; Bjerregaard, 1971) and any significant change in litterfall would result in changes in many ecosystem functions.

A total of 242 littertraps were sampled during 1983. Seven shrub species had 30-40 traps or replications placed beneath their canopies (Table 3.4-6). The seven species sampled were sagebrush, fourwing saltbush, shadscale (Atriplex confertifolia), Greenes rabbitbrush, hopsage (Grayia spinosa), Utah juniper, (Juniperus osteosperma), and greasewood. The litter traps were rectangular in shape with dimensions of 50 cm x 100 cm or 1/2 m^2 (Figure 3.4-4). The sides of the traps were 16 cm in height to prevent litter from blowing out of the traps. The bottom of the traps consisted of a fine mesh window screen which is small enough to catch most of the litter fragments, but will allow water to pass through and prevent decomposition. The 1981 litter traps did not have a fine enough screen for the six shrubs, but they were suitable for juniper. Thus, the 1981 traps were utilized exclusively under juniper in 1982 and 1983. The new 1/2 m^2 traps could be joined together to form a complete trap around a shrub. The typical placement of the 1m^2 litter traps is shown in Figure 3.4-5. A size index for each plant was also calculated so adjustments or comparisons could be made for litterfall amounts from small or large plants. The size index is computed by multiplying the height by the crown diameters (two directions) to

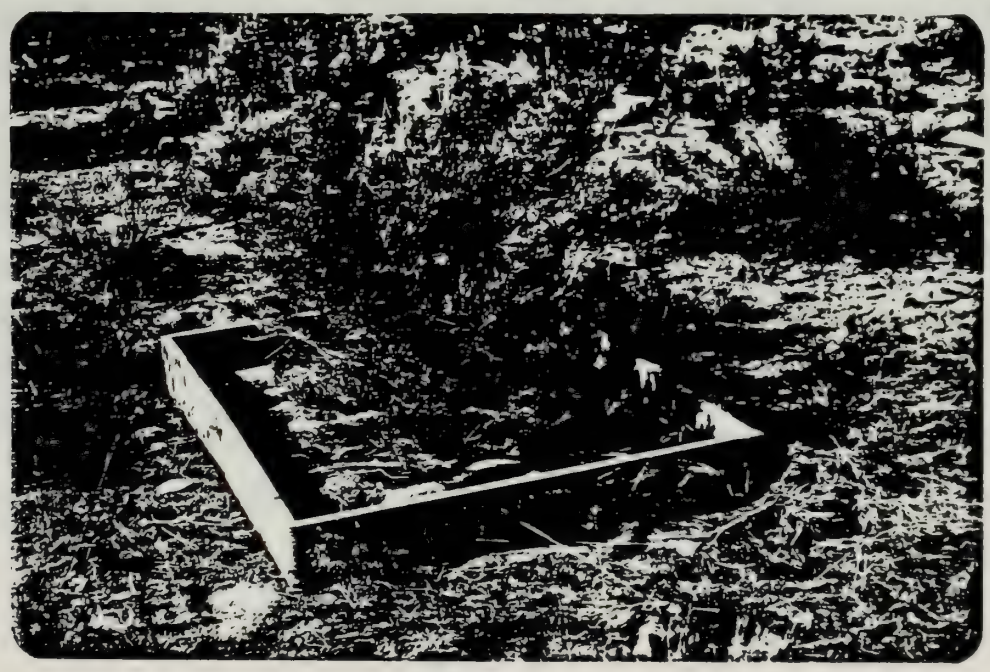
Table 3.4-6. General locations of species receiving litter fall catchments.

	Species							
Location[1]	ARTR	ATCA	ATCO	CHGR	GRSP	JUOS	SAVE	Subtotal
VS-1	4		10					14
VS-4	2		6					8
VS-5		9	6					15
VG-1	6	5		6	6		7	30
VG-2					6		6	12
VG-3	6			6			6	18
VG-4	6		5	6	7			24
VG-5	6		6	6			6	24
VJ-1						10		10
VJ-2						10		10
LC-1		10						10
LC-2		6				11		17
SLG-1							5	5
SLG-4				5	8			13
SLG-6	6		6	6	8		6	32
Total	36	30	39	35	35	31	36	242

[1] 15 sites

Figure 3.4-4. Typical placement of a 1/2 m^2 trap under greasewood.

Figure 3.4-5. Placement of two 1/2 m^2 litter traps under greasewood.



obtain a volume measure. If the crown diameter was over 1m then only 1 meter was used in the calculation of the size index since litter would otherwise fall outside of the trap. This approximates a volume figure which can then be used to compare different sized individuals within a species, as well as between species.

The litter traps were visited in April, June, and October and the litter for the corresponding period (i.e., June-October) was removed, placed in bags and the traps replaced. The litter samples were taken to the lab, oven dried for 14 days at 25°C, separated into components, i.e. leaf, stem, seed, inflorescence and mixtures of each and weighed. The results for weights for each species for April and June sampling periods were reported in the second and third quarterly reports. A summary table of the October samples is shown in Tables 3.4-7-13.

Table 3.4-14 shows the average monthly litterfall for each species for the four sampling periods. Litterfall measurement compares favorably to other values reported in the literature (West, 1979; Gottfried and Ffolliott, 1983). Figures 3.4-6 show the seasonality of the litterfall. Most species studied showed highest amounts during the summer when leaves are being dropped to reduce water stress. This is different from most forest ecosystems where late fall receives the greatest amounts (Gottfried and Ffolliott, 1983). Utah juniper had the greatest litterfall for the 16-month period (June 1982-October 1983). However, the plants were also the largest. On a per cubic unit basis, shadscale produced the most litter, followed by sagebrush with yield equivalents of 625.47 $g/m^3/yr$ and 197.92 $g/m^3/yr$, respectively (Table 3.4-15).

Table 3.4-7. Litterfall from juniper (JUOS) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
VJ1	1	2	49.5	37.8	4.3	7.4		
VJ1	2	2	30.7	27.2	2.4	1.1		
VJ1	3	2	33.9	32.4	1.50			
VJ1	4	2	13.8	12.6	1.2			
VJ1	5	2	29.8	29.5	0.3			
LC2	1	2	147.6	143.8	3.8			
LC2	2	2	38.0	28.1	8.5	1.4		
LC2	3	1	68.5	60.8	7.5	0.2		
LC2	4	2	57.5	55.2	2.3			
LC2	7	2	54.7	48.5	4.3	1.9		
LC2	8	2	122.6	106.5	7.6	8.5		
VJ2	1	2	59.6	30.5	9.5	19.6		
VJ2	2	2	32.8	21.0	2.2	9.6		
VJ2	3	2	22.8	17.6	4.8	0.4		
VJ2	4	2	40.5	35.2	4.7	0.6		
VJ2	5	2	22.8	18.0	3.6	1.2		
VJ3	1	2	42.3	37.7	3.0	1.6		
VJ3	2	2	30.7	28.0	2.7			
VJ3	3	2	75.8	53.2	5.7	16.9		
VJ3	4	2	35.4	31.3	3.5	0.6		
		$\bar{X}$	53.9 ± 38.3	45.7	4.6	3.6		
		% of total litter		85%	8%	7%		

*traps disturbed so no collections were possible; not included in the calculation of the mean.

**2 indicates that two $1/2m^2$ traps-placed under shrub, 1 means that one $1/2m^2$ trap was placed under the shrub. The weight values were doubled on the shrubs with only one $1/2m^2$ trap in the calculation of the mean.

***shrubs were heavily damaged by rabbits grazing.

Table 3.4-8. Litterfall from sagebrush (ARTR) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
SLG6	1	2	94.6	93.5	1.1			
SLG6	3	1	40.1	38.9	1.2			
SLG6	6	1	41.8	41.8				
SLG6	8	2	81.7	81.1	0.6			
VS1	1	1	18.5	18.5				
VS1	2	1	37.0	37.0				
VS1	3	2	21.8	21.5	0.3			
VS4	4	2	31.6	31.4			0.2	
VG1	5	2	53.2	53.2				
VG1	8	1	24.1	21.7	2.4			
VG1	10	1	28.3	28.3				
VG1	16	2	70.4	68.3	2.1			
VG3***	2	2	62.6	60.1	1.5		1.0	
VG3	9	1	11.8	11.5	0.3			
VG3***	10	1	32.0	25.3	4.8		1.9	
VG3	11	2	140.2	130.4	4.2		5.6	
VG4	10	2	58.8	58.8				
VG4	11	2	90.2	90.1	0.1			
VG4	13	1	24.9	24.9				
VG4	14	1	23.6	23.5	0.1			
VG5	4	2	37.1	36.9	0.2			
VG5	5	1	11.6	11.6				
VG5	6	1	15.2	15.2				
VG5	7	2	46.1	45.8	0.3			
		$\bar{X}$	58.6 ± 27.8	57.0	1.2		.4	
		% of total litter		97%	2%		1%	

Table 3.4-9. Litterfall from greasewood (SAVE) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
SLG6***	7	1	49.9	43.6	6.3			
SLG6	11	2	45.1	24.4				
SLG6***	21	2	109.9	70.9	39.0			
SLG6***	23	1	42.5	33.8	8.7			
SLG1*	1	2						
SLG1*	2	1						
SLG1	3	2	28.9	24.3	4.6			
VG1***	6	2	90.5	39.4	51.1			
VG1***	9	2	192.3	175.5	16.8			
VG1***	15	1	20.9	14.9	6.0			
VG1***	17	1	60.4		39.3	9.4		11.7
VG1	18	1	44.0	30.4	13.6			
VG2***	1	2	87.2	69.7	17.5			
VG2***	2	2	53.7	24.5	29.2			
VG2***	3	1	19.7	15.3	4.4			
VG2***	4	1	19.5	15.2	4.3			
VG3	3	2	60.2	46.4	13.8			
VG3	5	1	18.3	15.6	2.7			
VG3	8	1	30.3	21.8	8.5			
VG3	12	2	43.6	39.5	4.1			
VG5	2	2	51.6	30.0	21.6			
VG5	8	2	81.8	76.7	5.1			
VG5	10	1	26.8	23.0	3.8			
VG5	15	1	24.0	15.3	8.7			
		$\bar{X}$	70.8 ± 37.7	49.0	19.8	0.9		1.1
		% of total litter		69%	28%	1%		2%

Table 3.4-10. Litterfall from hopsage (GRSP) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
VG1***	12	2	23.1	21.1	2.0			
VG1***	14	1	38.7	37.1	1.6			
VG1	20	2	68.3	1.3				67.0
VG1	21	1	27.3	26.1	1.2			
VG2	5	2	8.2	7.3	0.9			
VG2	6	1	3.1	3.0	0.1			
VG2	7	1	8.2	8.0	0.2			
VG2	8	2	4.9	35.4	6.5			
VG4	1	2	14.3	14.3				
VG4	2	1	5.1	4.9	0.2			
VG4	3	2	13.4	13.3	0.1			
VG4	4	1	4.3	4.2	0.1			
VG4	5	1	3.3					3.3
SLG4***	3	1	21.4	18.0	2.4	1.0		
SLG4	5	1	52.1		2.0			soil
SLG4***	6	2	85.4	83.4	2.0			
SLG4	7	2	46.8	44.3	2.5			
SLG4***	8	2	76.1	68.4	7.7			
SLG6	12	1	15.2	13.3		0.9	1.0	
SLG6***	13	2	39.3	26.1	13.2			
SLG6	14	1	8.4	7.6	0.8			
SLG6	16	2	14.3	9.2	5.1			
SLG6	20	2	30.8	28.1	2.7			
		$\bar{X}$	34.7 ± 29.6	25.9	1.0	0.2		7.6
		% of total litter		75%	3%	1%		22%

Table 3.4-11. Litterfall from Green's rabbitbrush (CHGR) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
SLG	2	2	12.5		2.4			10.1
SLG6	17	1	28.6		8.5			20.1
SLG6***	18	2	36.7		15.5			21.2
SLG6	19	1	7.4		2.6			4.8
SLG4	1	2	2.7		1.7			1.0
SLG4***	2	2	20.0		5.9		6.5	7.6
SLG4	4	1	4.1		1.9			2.2
VG1	1	2	3.8		0.7			3.1
VG1	4	1	2.8					2.8
VG1	11	2	4.1		0.8		3.0	0.3
VG1	13	1	12.1		2.5			9.6
VG3***	1	2	37.9		9.6		28.3	
VG3	4	1	7.6		1.1		6.5	
VG3***	6	2	8.3		4.7			3.6
VG3***	7	1	10.0		4.3		0.6	5.1
VG4	7	1	6.5				6.5	
VG4***	8	1	1.3		0.7			0.6
VG4***	15	2	2.2		0.1			
VG4***	16	2	6.2		3.9			2.3
VG5	11	2	8.6		3.5			5.1
VG5	12	1	0.3	0.2	0.1			
VG5	13	1	0.3		0.3			
VG5	14	2	7.3		2.2			5.1
		$\bar{X}$	13.6 ± 14.1	0	5.1		2.8	5.7
		% of total litter			37%		21%	42%

Table 3.4-12. Litterfall from shadscale (ATCO) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
SLG6	4	1	16.2	11.8	4.4			
SLG6***	15	2	106.9		14.3			92.6
SLG6	22	2	54.2	45.6	8.6			
SLG6***	24	1	44.7	39.0	5.7			
VS5***	5	2	7.9	5.8	2.1			
VS5	6	1	8.6	7.9	0.7			
VS5***	7	2	37.8	26.1	11.7			
VS5	8	1	9.4	8.1	1.3			
VG5***	1	1	37.8	26.1	8.8	2.9		
VG5	3	1	32.8	32.4	0.4			
VG5***	9	2	130.2	87.0	43.2			
VG5	16	1	17.7		1.8			15.9
VS1	4	1	52.7		0.2			52.5
VS1	5	1	15.1	14.9	0.2			
VS1	6	1	20.1	19.8	0.3			
VS1	7	2	99.1		0.5	98.6		
VS1	8	2	9.7	9.6	0.1			
VS1	9	2	38.5	34.7	3.8			
VS1	10	1	52.8		0.1			52.7
VG4	6	2	23.8	21.1	2.7			
VG4***	9	2	23.0	20.0	3.0			
VG4	12	1	10.5	9.4	1.1			
VS4***	1	2	22.8		3.8			19.0
VS4	2	1	6.0	6.0				
VS4***	3	2	18.7	18.1	0.6			
VS4*	5	1						
		$\bar{X}$	48.9 ± 37.0	24.4	6.1	4.2	0	14.2
		% of total litter		50%	12%	9%	0	29%

Table 3.4-13. Litterfall from fourwing saltbush (ATCA) for the period June 6, 1983-October 10, 1983.

Location	Plant #	Catchment Size**	Litter Weight (g)	Litter Composition (g)				
				Leaf	Stem	Seed	Inflor	Mixture
LC2	5	1	0.9		0.6			0.3
LC2	6	1	2.9	0.7	0.5			1.7
LC2***	9	2	13.8	2.6	11.2			
LC2***	10	2	32.2	25.4	3.0	3.8		
LC1***	1	2	49.1	30.0	19.1			
LC1***	2	2	14.9	10.6	4.3			
LC1***	3	1	15.8		10.9			4.9
LC1***	4	2	31.0	21.1	8.0	1.9		
LC1	5	2	9.4	7.1	2.3			
LC1	6	1	8.8	8.6	0.1	0.1		
VG1***	2	1	24.7		12.6			12.1
VG1	3	1	10.1		4.9			5.2
VG1***	7	2	7.0		5.1			1.9
VG1***	19	1	17.8		9.1	1.6		7.1
VS5	1	2	12.9	5.7	7.2			
VS5***	2	1	48.8		8.3	5.9		34.6
VS5***	3	2	56.1		13.4	42.7		
VS5	4	2	15.7	12.5	2.7	0.5		
VS5	9	2						
		$\bar{X}$	27.9 ± 23.7	7.4	9.4	3.6	0	7.4
		% of total litter		27%	34%	13%		27%

Table 3.4-14. Litterfall on the seven species studied for a 16-month period. Values represent a monthly average for the period sampled. Values are expressed as grams of oven-dried biomass/meter^2.

	June-Oct. (82)	Oct.-April (82) (83)	April-June (83)	June-Oct. (83)	12-mo. total Oct. 1982 - Oct. 1983	16 mo. total June 1982- Oct. 1983
ARTR	45.04	11.40	3.23	58.60	73.23	118.27
SAVE	41.39	23.30	6.03	70.86	100.13	141.52
GRSP	32.00	2.90	0.93	34.70	38.53	70.53
CHGR	14.87	12.70	1.90	13.60	28.20	43.07
ATCO	26.36	40.40	4.52	48.90	93.82	120.18
ATCA	54.35	69.10	11.43	27.90	108.43	162.78
JUOS	112.44	14.90	29.56	53.90	98.36	210.80

Table 3.4-15. Litterfall composition, total litterfall, size indexes, and total litter per size index for each of the seven species studied for the period June 1982-October 1983.

Species	% Leaf	% Stem	% Seed	Inflor.	Mixtures	Total/m	SI	Litter (g)/Size Index/Yr
ARTR	89	5		1	5	73.23	.37	197.92
SAVE	48	39	1		12	100.13	.65	154.05
GRSP	60	17			23	38.53	.39	98.79
CHGR	4	44		16	36	28.20	.33	85.45
ATCO	47	18	4		31	93.82	.15	625.47
ATCA	39	23	30		8	108.43	.72	150.60
JUOS	88	8	3		1	98.36	2.70	36.43

A comparison of results for 1982 with 1983 are limited since only the June-October period overlap; however, comparisons are shown in Table 3.4-14 and Figure 3.4-6.

3.4.5 Assessment of Animal Use of Plants

The monitoring of animal use of plants is important during the construction and operational phase of the White River Shale Project. Impacts of the operation on browsing animals may be reflected through their use of browse shrub species (i.e., heavier or lighter utilization than the average usage).

To assess the use on the tracts, the Cole Browse Survey was run at six sites using three key species in April of 1983. Overall animal use of key shrub species in 1983 was light (18% leader use) compared with 1982 (51% leader use), perhaps due to the greater shrub productivity which increased the availability of food. Shrub usage was attributed primarily to sheep which were observed grazing at the time of sampling near the transects in the shadscale and greasewood vegetation types. Signs of rabbits and to a lesser extent, deer browsing were also observed along the transects.

Results of the Cole Browse Survey are given in Table 3.4-16. Shadscale received heavier leader usage (41%) than greasewood (17%) or sagebrush (4%). Form class, an indication of browsing received from the previous two years, showed that shadscale again received the heaviest usage with 46% of the plants being in the heavily used category. Form class and age class together indicate the allowable browse usage of a particular species.

Shadscale and greasewood had 36% and 32%, respectively, of the plants within the decadent age class and none in the seedling and few in the younger

Figure 3.4-6. Seasonal distribution of litterfall over the 16 months of sampling. Values represent monthly averages for the period between collection.

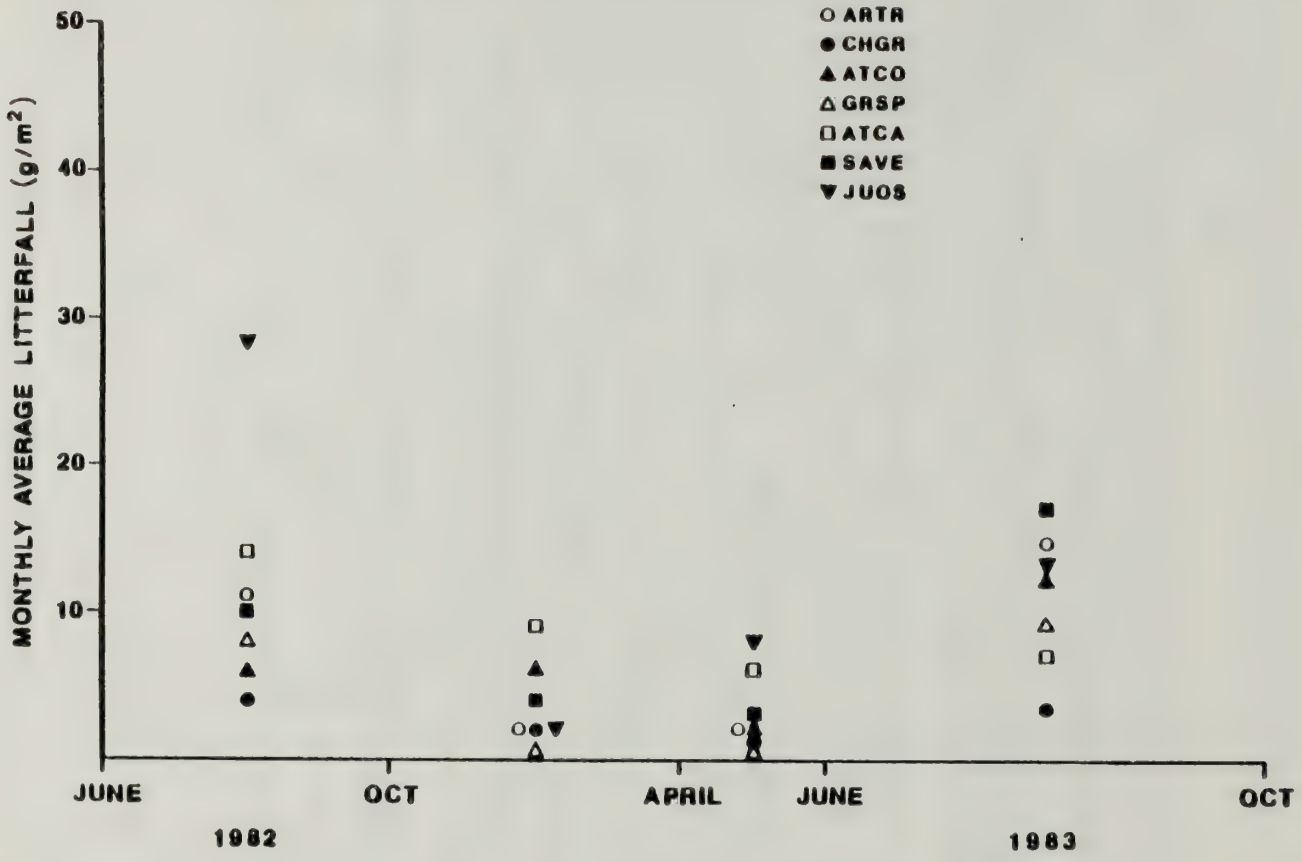


Table 3.4-16. Results of Cole Browse Survey taken in April 1983.

Species Sampling Site	Form Class % None	Lt.-Mod.	Heavy	Dead	Age Class% Seedling	Young	Mature	Decad.	% Leader Use
ATCO									
VS1	0	44	52	4	0	4	56	40	32
VS5	0	52	40	8	0	8	60	32	49
$\bar{x}$	0	48	46	6	0	6	58	36	41
ARTR									
VG2	56	44	0	0	0	16	76	8	2
VG1	40	45	15	0	0	5	95	0	7
SLG6	75	25	0	0	0	0	85	15	2
$\bar{x}$	57	38	5	0	0	7	85	8	4
SAVE									
VG4	4	84	8	4	0	12	80	8	15
VG3	0	44	36	20	0	8	36	56	18
$\bar{x}$	2	64	22	12	0	10	58	32	17

Table 3.4-17. Leader lengths of caged and non-caged big sagebrush shrubs.

	Leader length (mm) caged	Leader length (mm) non-caged	T	Significance
VG1	43.4	39.3	1.03	ns
SLG6	50.6	43.2	1.04	ns

age class. This trend is probably characteristic of an arid or semi-arid environment where seedling establishment occurs commonly only in favorable years (once in ten to twenty years).

Caged plots were established in October 1982 at SLG6 on the north side of the White River and VG1 at the head on Southam Canyon (Figure 3.4-7). The length of 20 leaders from each caged shrub (plot) and an adjacent non-caged shrub was measured in April, 1983. Results of the data were tested statistically and showed that there was no significant difference in leader length at either sites sampled (Table 3.4-17). However, in both sites, the caged plants had longer average leader lengths than the uncaged plants (VG1-110%; SLG6-117%). No difference between caged and non-caged shrubs indicate minimal or no browsing. The Cole Browse Survey was also taken at these sites and also indicated minimal leader use (5%).

3.4.6 Use of Lichens as Biological Monitors of Air Pollution

The use of lichens as indicators of air quality has been documented and in many cases implemented throughout many parts of the world. Lichens have been used to monitor the effects of air pollutants in a variety of ways. In areas surrounding coal-fired power generating plants, the elemental concentrations of the lichen thallus have been evaluated and compared with unaffected areas (Gough and Erdman, 1977; Erdman and Gough, 1977; and Nash and Sommerfield, 1981). In situations where lichens are lacking, lichen species have been transplanted into the area and their condition closely monitored (Ferry and Coppins, 1979). Changes in the characteristics of the lichen community are also monitored. A reduction in the number of species per unit area, or the demise of a particular

Figure 3.4-7. Illustration of cages placed over sagebrush to assess browse utilization.

species can be detected with close examination of the lichen community (Marsh and Nash, 1979; Nash, 1974; Sigal and Nash, 1983).

The use of lichens as biological monitors of air pollution is not by accident. Particular groups of lichens, primarily the foliose and fruticose lichens, show a high sensitivity to increases in air pollutants, especially SO_2 (Nash, 1973). SO_2 apparently breaks down the cell membranes causing severe damage and visually recognizable symptoms (Beckerson and Hofstra, 1979; Beekley and Hoffman, 1981; Pearson and Henriksson, 1981; Henriksson and Pearson, 1981). It has been noted that lichens are more sensitive to air pollutants than are vascular plants (Eversman, 1978) and, therefore, any detectable damage to lichens serves as an early indicator of potential pollution damage to vascular species.

The purpose of this phase of the monitoring program is to first, document the existing conditions of the saxicolous lichen community within the proposed development area of the White River Shale Project, and second, to develop procedures/methodologies for measuring the existing condition of the lichen communities and for detecting alterations in that community that may be attributable to oil shale development activities.

Characterization of 18 saxicolous lichen communities along three transects radiating out from the proposed plant site was initiated with 1982 field studies and continued in 1983. Stands at the four and six mile mark of the northeast transect and the six-mile mark of the southeast transect consist of photo-plots only, due to the absence of a large enough sample area. Parameters measured at each stand include: total cover (an ocular estimate of the cover attributable

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to both lichens and mosses), the number of species per quadrat, and the frequency of each saxicolous lichen. In addition to the ecological parameters measured, a permanently marked photo-plot was again photographed in 1983. These permanent plots will serve as a visual means of detecting changes in the lichen community.

Results of the 1983 lichen monitoring study are presented by transect in Tables 3.4-18 to 3.4-20 . The frequency of each species is reported and the amount of lichen cover and the number of species encountered per quadrat are summarized for each of the permanently marked transects.

A total of 32 species of saxicolous and terricolous lichens were encountered along the northwest transect. Twenty seven were recorded for the northeast transect and 23 for the southeast transect. Lecidea russelli was the only terricolous lichen found along any of the three transects. It was found growing on small soil pockets or mosses on the northerly exposed rock surfaces.

The average number of species encountered per quadrat for all transects sampled during 1983 was 7.0 species/quadrat. A low of 5.5 species/quadrat was reported at stand 1 along the northwest transect. The most species encountered per quadrat was at stand 1 of the southeast transect (9.05). The average amount of lichen cover for all 18 stands was 28.4%. Cover values ranged from a high of 49.9% at stand 1, southeast transect, to a low of 15.45% at stand 3 along the northwest transect (Table 3.4-21).

Conclusions drawn from the 1982 lichen monitoring study suggested a special emphasis in 1983 on selecting dominant lichen species to be used in the lichen monitoring program. Many lichen species occur only rarely, others are not

Table 3.4-18. Frequency of all lichen species encountered along the NW transects, 1983.

Species	Stands 1	2	3	4	5	6	7
Acarospora strigata	1.00	.90	.90	.85	.74	.70	.80
A. chlorophana	----	----	.05	----	.25	----	----
A. glaucocarpa	.05	.20	----	----	----	.25	.20
A. schleicheri	----	----	----	----	----	----	----
A. smaragdula	.20	.40	.45	.45	.50	.55	.10
Buellia punctata	----	----	----	.05	----	----	.05
B. retrovertans	----	----	----	----	----	.60	----
B. saurina	----	----	----	----	.10	----	----
Caloplaca epithallina	----	----	----	.05	----	----	----
C. trachyphylla	.05	.10	.20	.45	.35	.35	.15
Canderlariella rosulans	.75	.80	.75	.75	.35	.75	.65
Collema sp.	----	----	----	.15	----	----	----
Dermatocarpon miniatum	.10	----	----	.10	.10	----	----
Lecanora alphoplaca	.30	.05	.10	.15	.25	----	----
L. caesiocinerea	.50	.60	.40	.60	.55	.70	.70
L. calcarea	.05	.00	----	----	----	----	----
L. chrysoleuca	----	----	----	----	----	----	----
L. frustulosa	----	.15	----	----	----	----	----
L. garovaglii	.15	----	.10	.15	.20	.15	----
L. melanothalma	.15	----	----	.15	.05	.30	----
L. muralis	.15	.20	.25	.25	.50	.35	.55
L. mutablis	.10	.35	.65	.50	.30	.50	.95
L. novomexicana	----	----	----	.05	.30	----	----
L. peltata	.10	.30	.25	.40	.30	.45	.65
Lecidia auriculata	----	.20	.25	.20	.10	.05	.65
L. globifera	----	----	----	----	----	----	----
L. novomexicana	----	.15	.05	----	----	----	----
L. plana	----	----	----	----	----	----	----
L. russellii	----	----	.05	.25	.05	----	----
L. stigmata	.40	.60	.75	.65	.15	.65	.65
L. tesselata	----	----	.05	----	----	----	----
Parmelia substygia	----	----	.04	.25	.20	----	----
Physica sp.	----	----	----	----	----	----	----
Rhizocarpon disporum	----	----	----	----	.25	----	----
Sarcogyne privigna	----	----	----	----	----	----	.30
Staurothele rufa	.95	1.0	.50	.60	.70	.85	.85
No. Spp./Quadrat	5.50	6.5	5.95	7.25	6.45	7.00	6.60
Avg. % Cover	19.6	21.6	15.45	21.1	22.8	26.25	28.00

Table 3.4-19. Frequency of all lichen species encountered along the NE transects, 1983.

Species	Stands 1	2	3	4	5
Acarospora strigata	.80	.70	.90	.90	.30
A. chlorophora	----	----	.10	----	----
A. glaucocarpa	.05	.35	----	.30	.25
A. schleicheri	----	----	----	----	----
A. smaragdula	.25	----	.45	.45	.40
Buellia punctata	.35	.30	----	.05	.10
B. retrovertans	----	----	----	----	----
B. saurina	.20	----	----	.15	.10
Caloplaca epithallina	----	----	----	----	----
C. trachyphylla	.70	.85	.65	.75	.85
Candelariella rosulans	.65	.90	.90	.65	.95
Collema sp.	.20	.30	----	----	.20
Dermatocarpon miniatum	.30	.10	----	----	.40
Lecanora alphaplaca	----	.15	----	----	.20
L. caesiocinerea	.55	.75	.70	.90	.50
L. calcarea	----	----	.05	----	----
L. chrysoleuca	.05	----	----	----	----
L. frustulosa	----	----	----	----	----
L. garovaglii	.15	----	----	.45	----
L. melanothalma	.15	----	----	----	----
L. muralis	.05	----	.20	.15	.40
L. mutabilis	.40	.80	.75	.70	.65
L. novomexicana	----	----	.30	----	----
L. peltata	.15	.20	.60	.25	.65
Lecidia auriculata	.40	.20	.55	.15	.50
L. globifera	----	----	----	----	----
L. novomexicana	----	----	----	----	----
L. plana	----	----	----	----	----
L. russellii	----	.25	.10	----	----
L. stigmata	.55	.75	.90	.70	.85
L. tesselata	----	----	----	----	----
Parmelia substygia	----	.15	----	----	----
Physica sp.	----	----	----	----	----
Rhizocarpon disporum	.25	.05	----	.05	.20
Sarcogyne privigna	----	.20	----	.20	----
Staurothele rufa	.70	.95	.70	.90	.55
No. Spp./Quadrat	7.05	7.70	7.85	7.70	8.10
Avg. % Cover	29.95	40.0	25.55	26.50	36.55

Table 3.4 - 20. Frequency of all lichen species encountered along the SE transects, 1983.

Species	Stands 1	2	3	4	5	6
Acarospora strigata	.55	.90	.85	.80	.60	.65
A. chlorophana	----	----	----	----	----	----
A. glaucocarpa	----	----	----	.15	.05	.10
A. schleicheri	----	----	----	----	----	----
A. smaragdula	.60	.25	.20	.30	.60	.40
Buellia punctata	.10	----	----	.25	.15	.05
B. retrovertans	----	----	----	----	----	----
B. saurina	----	----	----	.15	.20	.25
Caloplaca epithallina	.05	----	----	----	.10	----
C. trachyphylla	.65	.70	.20	.80	.95	.95
Candelariella rosulans	145	.85	.90	.90	.95	.95
Collema sp.	----	----	----	----	----	----
Dermatocarpon miniatum	----	----	----	.20	.05	----
Lecanora alphoplaca	.15	----	----	----	----	.10
L. caesiocinerea	.95	.60	.85	.70	.90	.80
L. calcarea	----	----	----	----	----	----
L. chrysoleuca	----	----	----	----	----	----
L. frustulosa	.65	----	----	----	----	----
L. garovaglii	.95	----	----	.15	.50	.15
L. melanothalma	----	----	----	----	----	----
L. muralis	.35	.10	.25	.05	----	.20
L. mutabilis	.05	.65	.50	.85	.80	.50
L. novomexicana	.80	----	.10	.30	----	----
L. peltata	.40	.25	.45	.20	.20	.10
Lecidia auriculata	.10	.45	.20	.40	.30	.70
L. globifera	----	----	----	----	----	----
L. novomexicana	----	----	----	----	----	----
L. plana	----	----	----	----	----	----
L. russellii	----	.10	----	----	----	----
L. stigmata	.35	.35	.50	.45	.85	.75
L. tesselata	----	----	----	----	----	----
Parmelia substygia	.25	----	----	.05	----	----
Physica sp.	----	----	----	----	----	----
Rhizocarpon disporum	.55	----	----	.05	----	.15
Sarcogyne privigna	----	----	----	----	----	----
Staurothele rufa	.85	.85	1.00	.70	.20	.20
No. Spp./Quadrat	9.05	6.05	6.00	7.45	7.45	7.00
Avg. % Cover	49.90	25.25	25.90	31.35	35.10	33.8

Table 3.4 -21. Comparison of lichen monitoring stands based on 1982 and 1983 values estimated for average % cover and average number of species/quadrat. Fisher Mean Separation test was used to identify significant differences between stands. Lettering (a,b) indicates differences between transect pairs i.e., SE1-1983 and SE1-1982, are significant. Differences indicated only for those with a significant F-value.

Transect	Stand No.	% Cover			#Spp./Quadrat		
		1982	1983	F-value	1982	1983	F-value
NW	1	18.80	19.60	1.11^{ns}	6.25^{a}	5.50^{a}	4.9**
NW	2	19.50	21.60		6.00^{a}	6.50^{a}	
NW	3	12.80	15.45		5.65^{a}	5.95^{a}	
NW	4	23.45	21.10		7.05^{a}	7.25^{a}	
NW	5	25.65	22.80		8.95^{a}	6.45^{b}	
NW	6	21.15	26.25		7.30^{a}	7.00^{a}	
NW	7	25.2	28.00		6.30^{a}	6.60^{a}	
NE	1	31.35^{a}	29.95^{a}	3.2*	8.15	7.05	1.4^{ns}
NE	2	34.80^{a}	40.00^{a}		7.95	7.70	
NE	3	28.65^{a}	25.55^{a}		8.10	7.85	
NE	4	24.55^{a}	26.50^{a}		8.15	7.70	
NE	5	48.30^{a}	36.55^{b}		9.70	8.10	
SE	1	32.30^{a}	49.90^{b}	5.9**	7.65^{a}	9.05^{b}	4.4**
SE	2	25.30^{a}	25.25^{a}		6.85^{a}	6.05^{a}	
SE	3	25.25^{a}	25.80^{a}		7.20^{a}	6.00^{b}	
SE	4	26.05^{a}	31.35^{a}		7.85^{a}	7.45^{a}	
SE	5	42.40^{a}	35.10^{b}		9.40^{a}	7.45^{a}	
SE	6	30.10^{a}	33.80^{a}		7.40^{a}	7.00^{a}	

* Significant at $\alpha \leq .05$
** Significant at $\alpha \leq .01$

easily recognized due to weathering, and some lichen species are not easily distinguished from other species without microscopic examination. It became necessary to select from the 32 species of lichens that have been identified and encountered at stands along the three transects, a representative core of species for use in the lichen monitoring program. The selection criteria was based on overall frequency of each of the 32 species. The species were ranked according to frequency of occurrence and the eight species with the highest frequency values were selected. Eight species were selected since the average number of species encountered per quadrat was 7.3 (average for all stands for both years, Table 3.4-21). The frequency for each species was averaged for both years and for all stands (Table 3.4-22). Lecanora peltata was selected over Acarospora smargdula, even though its overall frequency value was lower (.36 to .39) because L. peltata is a foliose species and will serve as a better monitor of atmospheric conditions than A. smargdula, a crustose species. The occurrence of all lichen species will continue to be recorded each year of development to determine the average number of species occurring per quadrat, which has been shown to be an important monitoring parameter (Sigal and Nash, 1983. Special emphasis will be given the assessment of the occurrence of these species.

A key issue in using lichens to monitor the effects of changes in the environment is the year to year consistency with which the lichen communities can be sampled. From the 1982 data collected on lichen sampling methods a level of sampling adequacy was determined. Now with two years data, the next issue is the comparability of the 1982 data with that collected in 1983. To test this issue an analysis of variance (ANOVA) test was made to evaluate differences

Table 3.4-22. Selection of 8 most abundant species for the lichen monitoring program. Asterisk indicates those 8 species selected.

Species	Avg. Frequency 1982 & 1983
Acarospora strigata	.79*
A. chlorophana	<.01*
A. glaucocarpa	.12
A. schleicheri	<.01
A. smaragdula	.39
Buellia punctata	.16
B. retrovertans	<.01
B. saurina	<.05
Caloplaca epithallina	<.01
C. trachyphylla	.57
Canderlariella rosulans	.77*
Collema sp.	.04
Dermatocarpon miniatum	.08
Lecanora alphoplaca	.09
L. caesiocinerea	.67*
L. calcarea	.04
L. chrysoleuca	<.01
L. frustulosa	<.01
L. garovaglii	.16
L. melanothalma	.04
L. muralis	.20
L. mutabilis	.58 *
L. novomexicana	.13
L. peltata	.36 *
Lecidia auriculata	.27
L. globifera	<.01
L. novomexicana	<.01
L. plana	<.01
L. russellii	.02
L. stigmatea	.51*
L. tesselata	<.01
Parmelia substygia	.04
Physica sp.	<.01
Phisocarpon disporum	.09
Sarcogyne privigna	<.01
Staurothele rufa	.70*

between stands for 1982 and 1983 based on % lichen cover and number of species/quadrat. This was done separately for each transect. The results are presented in Table 3.4-21. Based on % lichen cover three stands differed significantly between years. Cover values for the NE5 stand decreased from 48.3% to 36%.55, a significant change. The SE1 stand and the SE5 stand were also significantly different between years. SE1 increased from 32.3% to 49.9% and SE5 decreased from 42.4% to 35.1%.

Four of the 18 stands differed from 1982-1983 based on number of species per quadrat. The NW5, SE3 and SE5 stands, all showed decreases in the number of species/quadrat. Stand SE1 increased from 7.65-9.05.

Analysis comparing 1982 and 1983 frequencies of the eight most prevalent species showed a significant difference for one species, Lecidea stigmatea (Table 3.4-23). This may be attributable, in part, to the similarity of other crustose species such as Buellia and L. aurreulata to L. stigmatea which caused observer error in classification.

Baseline monitoring of the lichen communities prior to plant start up will eliminate much of the variation and differences encountered. Familiarity with the prevalent species and some of the expected physical aberrations of the species will further refine the monitoring techniques. The differences between percent cover, number of species, quadrat and frequency between 1982 and 1983 will not be eliminated by refining sampling methodology, however. Much of the variation is due to the heterogenity of the lichen communities found at each of the stands. The physical area they occupy is relatively small compared to vascular plant communities. Within this small area numerous microsites occur

Table 3.4 - 23. Comparisons of key monitoring parameters between 1982 and 1983. Figures are averages over all 18 stands. Species listed in order of highest to lowest frequency.

Parameter	Year 1982	1983	F-value
% Cover	27.54	28.43	$.3^{ns}$
# Spp./Quadrat	7.55	7.04	4.1^{ns}
% Frequency			
Acarospora strigata	$.80^{a}$	$.77^{a}$	7.3^{**}
Candelariella rosulans	$.77^{a}$	$.77^{a}$	
Staurothele rufa	$.71^{a}$	$.73^{a}$	
Lecanora caesiocinerea	$.65^{a}$	$.68^{a}$	
Lecanora mutabilis	$.61^{a}$	$.56^{a}$	
Caloplaca trachyphylla	$.57^{a}$	$.56^{a}$	
Lecidea stigmatea	$.35^{a}$	$.60^{b}$	
Lecanora peltata	$.40^{a}$	$.33^{a}$	

which favor one species over another. The permanent stands were placed in as homogeneous an area as possible, but even in a short distance of 20 meters several microsites will be encountered.

Based on the results of 1982 and 1983 data the lichen monitoring program should continue as outlined in the Environmental Monitoring Manual. The percent cover of saxicolous lichen, number of lichen species/quadrat, and the frequency of the 8 most prevalent species will be the key parameters measured.

Experimentation continues in the laboratories of NPI to assess the feasibility of using membrane permeability analysis to assess lichen condition. The results of those experiments will be present in 1984 progress reports.

3.4.7 Plant Condition and Stress

One means of monitoring manifestations of damage due to causal agents is to regularly inspect individual plants. However, this technique is generally impractical for surveys of large areas where accessibility is limited and vegetation is rather sparse. Its use is generally restricted to small areas where the location or frequency of adverse effects is certain. Permanent plots are usually associated with this approach to monitoring. The relative complexity of the vegetation on the oil shale tracts, the large area to be surveyed, and general inaccessibility of some areas, limits the value of this approach for monitoring vegetation condition/stress on lands associated with the White River Shale Project. Alternatively, effective monitoring can be achieved by remote sensing using color infrared (CIR) photography. Color and color infrared aerial photographs have proved to be more reliable and accurate sensors for detecting change in vegetation than black and white films or ocular

estimates (Heller, 1978). The photographs offer a permanent record which can be used as baseline data and can be subsequently checked with new photography at a future date. In many cases, a survey can be made of comparable accuracy with less money, less time and with fewer people than by conventional ground survey methods (Wert and Rottgering, 1968).

The use of CIR photography as an aid to monitoring vegetation damage is based on the fact that physiological changes reveal themselves photographically through changes in spectral reflectance. Changes in spectral reflectance may first occur at wavelengths beyond detection with the human eye or normal color film. By the use of color infrared film, these previsual or extra-visual symptoms can be detected and recorded. Healthy vegetation regardless of vegetation type or species, usually appears a reddish color on CIR film positives or prints. Stressed vegetation grades with intensity of stress to magenta, purple, green and yellow as the loss of infrared reflectance processes. It is, therefore, the deviation relative to the appearance of healthy vegetation that becomes important in detecting vegetation stress.

Vegetative cover on portions of oil shale tracts Ua and Ub was photographed from a fixed-wing aircraft on July 19, 1982 and August 5, 1983. These dates coincide with the maximum stress period as determined by the phenological stage of annual plant species such as cheatgrass, halogeton and Russian thistle.

Photographic specifications followed those detailed in the Environmental Monitoring Manual (EMM). The sequence of photographs, taken at predetermined altitudes, constitute a transect that documents the condition of vegetation along that portion of the study area. Two such transects were flown within the

study area (Figure 3.3-1). Both traverse the proposed plant site in Sec. 22 (T.10S, R.24E) and were flown at an altitude of 600 feet above ground level, resulting in an image scale ratio of approximately 1:2,400. The transects are approximately 0.5 miles wide and 8 miles long. The first of these transects was centered along the pathway of maximum plume effluent discharge from the proposed retort in a NW-SE direction. The second transect is oriented at approximately right angles to the first transect, a NE-SW direction and is expected to receive minimal gaseous discharge levels. Both transects traverse all four vegetation types as delineated in the baseline report.

Ground reconnaissance of the transects conducted in 1982 was preceded by an assessment of each CIR photograph for stressed vegetation. Vegetation showing stress as depicted by deviation from high infrared reflectance (a reddish color) was clearly marked. Once a preliminary assessment was made, the photographs were taken to the field where stressed areas were visited, and data taken as to the causal factor and frequency of the stress. During the ground reconnaissance a coding system was developed in which each stressed area or individual plant was identified as to aerial photograph number, color photograph number, vegetation type, causal factor, if detectable, and the species affected. The results of the ground reconnaissance are presented in the 1982 Final Report.

Aerial photographs taken in August of 1983 were similarly analyzed, except ground reconnaissance was restricted to areas differing significantly from 1982 photography. The objective of the 1983 analysis was to quantify the information obtained from the CIR aerial photography taken in 1982 and 1983. This quantification is presented in Table 3.4-24. Overall there was little

Table 3.4-24. Summary of data collected on plant stress using CIR photography, 1982 and 1983. Figures represent the number of individual plants determined to be stressed per one square mile.

Transect	Flight Line No.	Area Sampled (sq. miles)	Utah Juniper 1982	Utah Juniper 1983	Pinyon Pine 1982	Pinyon Pine 1983	Other 1982	Other 1983	Total 1982	Total 1983
NW	5	1.6	15.6	15.6	--	--	1.9	1.9	17.5	17.5
NW	6	1.5	10.0	12.0	--	--	1.9	0	11.9	12.0
SW	7	1.1	12.7	12.7	--	--	--	--	12.7	12.7
SW	8	1.1	30.9	30.9	--	--	2.7	0	33.6	30.9
NE	9	0.9	11.1	10	--	--	4.4	4.4	15.5	14.4
NE	10	0.95	4.2	6.3	--	--	1.1	1.1	5.3	7.4
SE	11	1.0	8	9	--	--	1	1	9.0	10.0
SE	12	1.1	3.6	3.6	2.7	2.7	0.9	0.9	7.2	7.2
Total		9.25	96.1	100.1	2.7	2.7	13.9	9.3	112.7 (12.2 sq. mi)	112.1 (12.1 sq. mi)

difference noted between 1982 and 1983 CIR photography. The differences encountered were attributable to increased resolution of one years' photographs to the others. For example, the average number of stressed juniper trees per square mile increased from 10 to 12 on the No. 6 flight line (NW transect) and from 4.2 to 6.3 on flight line 10 (NE transect). In both instances the difference was attributable to increased resolution on the 1983 photographs. Shadows prohibited a firm determination of stress in the 1982 photographs. In the instance of flight lines 6 (NW transect) and 8 (SW transect) in the "other" category the number of individuals was actually reduced. This again was due to the higher resolution of riparian areas along both transects on the 1983 photographs. Trees determined to be stressed in 1982 were actually dead and down with decadent understory material giving the appearance of stress.

Additional overflights of the transects are not now planned until plant start up. It is felt that the CIR photography taken in 1982 and 1983 has established a good overall base for future monitoring efforts. All CIR photography has been catalogued at NPI and can be easily assessed for comparisons with post plant-start up overflights.

3.4.8 Soil Microbiology and Soil Chemistry

Sampling for soil microbiology and chemistry occurred in January, April, July, and October 1983 along transects at eight sites within or adjacent to oil shale tracts Ua and Ub (Figure 3.3-1). Soils were collected as in 1981 and 1982. All samples were sieved using a 2 mm screen and analyzed for moisture content, pH, EC, organic carbon, total bacteria, total fungi, total algae, respiration, and dehydrogenase activity. Methods for analyses were identical to

those described in the EMM, 1982. Measures of moisture content and microbiological analyses were performed on fresh soils within a week of collection. The pH, EC, and organic carbon assays were performed on air dried samples. Results from the October sampling are shown in Tables 3.4-25-26. The October samples represent the final samples for 1983. The yearly summary for 1983 is reported in Table 3.4-27. Yearly trends and analyses for all samples in 1983 follow, as well as, comparisons with 1981 and 1982 data.

3.4.8.1 Soil Moisture Content Mean soil moisture content (all sites, all depths) fluctuated from a January high of 22.5% to a July low of 1.1% (Table 3.4-27, Figure 3.4-8). During summer months, moisture levels were slightly higher in subsurface (5-15 cm) soils than in surface soils (0-5 cm). In winter months, surface soils generally contained 5-10% more moisture than subsurface soils. There are significant differences in soil moisture content between sites and months (Table 3.4-27, 28). Riparian soils (VR1) had significantly more moisture than upland soils. Site VS1 also was significantly higher than the remaining six sites although it was less than VR1. Sites VS4 and VJ5 had the lowest average soil moisture content on an annual basis, averaging 8.11 and 9.4% respectively. These patterns closely paralleled those found in 1981 and 1982 although 1982 and 1983 moisture levels were generally 3-4% higher than those recorded in 1981. A major difference in 1983 was the high soil moisture levels for the April sampling. These were nearly double the 1981 and 1982 samples for April soil moisture. This may be a major reason for the high annual biomass production in 1983.

3.4.8.2 pH and EC Soil pH's averaged 7.9 in the 0-5 cm zones and 8.2 in

Table 3.4-25. Results of soil chemistry analysis, October 1983.

Transect	Depth (cm)	Moisture (%) Mean	Moisture (%) Std. Dev.	pH Mean	pH Std. Dev.	EC (mmhos/cm^2) Mean	EC (mmhos/cm^2) Std. Dev.	Organic carbon (%) Mean	Organic carbon (%) Std. Dev.
VS1	0-15	6.53	1.22	7.70	0.51	0.21	0.02	1.43	0.15
	5-15	5.92	0.78	8.09	0.19	0.19	0.02	1.08	0.15
VS4	0-5	3.98	0.07	8.14	0.13	0.19	0.04	0.83	0.11
	5-15	4.36	0.20	8.57	0.43	0.22	0.05	0.66	0.04
VG1	0-5	3.57	0.39	7.68	0.24	0.18	0.05	1.06	0.09
	5-15	4.09	0.43	7.91	0.21	0.14	0.02	0.56	0.22
VG2	0-5	3.58	0.36	7.50	0.07	0.21	0.05	1.36	0.45
	5-15	3.86	0.11	7.85	0.26	0.19	0.03	0.88	0.28
VG3	0-5	2.92	0.19	7.71	0.05	0.30	0.05	0.91	0.04
	5-15	3.01	0.20	7.85	0.04	0.17	0.03	0.44	0.05
VJ1	0-5	3.34	0.25	7.58	0.06	0.25	0.11	1.45	0.68
	5-15	4.10	0.29	7.85	0.06	0.20	0.04	0.98	0.24
VJ5	0-5	3.75	0.21	7.67	0.22	0.33	0.11	1.16	0.51
	5-15	3.89	0.22	8.12	0.35	0.26	0.10	0.71	0.27
VR1	0-5	3.80	0.37	7.59	0.11	0.88	0.13	2.05	1.55
	5-15	4.22	0.60	7.94	0.34	0.60	0.23	0.86	0.40
$\bar{Y}$	0-5	3.93	1.10	7.70	0.19	0.32	0.23	1.28	0.39
	5-15	4.18	0.94	8.02	0.25	0.25	0.15	0.77	0.22

Table 3.4-26. Results of soil microbiology analysis, October 1983.

Transect	Depth (cm)	Total Fungi (m hyp/g) Mean	Total Fungi (m hyp/g) Std. Dev.	Total Bacteria (10^6 cfu/g) Mean	Total Bacteria (10^6 cfu/g) Std. Dev.	Respiration (meq CO_2/g/hr) Mean	Respiration (meq CO_2/g/hr) Std. Dev.	Dehydrogenase (mg formazan/l) Mean	Dehydrogenase (mg formazan/l) Std. Dev.
VS1	0-5	19.42	17.21	17.8	1.4	4.20	1.72	16.6	1.9
	5-15	24.43	10.39	10.2	2.0	2.30	1.90	6.5	2.4
VS4	0-5	7.99	4.00	7.9	3.7	3.03	0.98	11.2	2.6
	5-15	23.16	13.63	7.7	2.9	3.21	0.87	3.3	2.1
VG1	0-5	2.22	3.84	14.5	2.3	1.43	0.45	12.0	1.3
	5-15	8.90	5.41	8.6	0.7	1.91	0.91	2.9	0.6
VG2	0-5	12.83	4.68	18.9	6.1	2.64	1.56	16.2	4.4
	5-15	31.47	5.38	12.5	2.8	1.34	0.67	7.2	2.1
VG3	0-5	7.03	5.49	20.6	13.4	0.48	0.42	10.8	2.6
	5-15	10.99	7.73	13.9	8.3	0.77	0.24	2.2	0.7
VJ1	0-5	18.50	12.57	6.6	1.2	1.08	0.64	11.9	3.5
	5-15	32.00	13.89	8.6	0.5	1.21	0.61	7.4	1.3
VJ5	0-5	7.98	13.83	7.9	2.1	1.39	0.67	100	3.7
	5-15	11.52	3.83	9.5	1.2	2.12	0.92	3.9	1.5
VR1	0-5	12.84	9.98	31.8	17.3	2.90	0.79	12.3	2.2
	5-15	11.55	4.98	10.6	5.6	2.56	0.72	3.0	0.4
$\bar{X}$	0-5	11.10	5.91	15.8	8.5	2.14	1.24	12.6	2.5
	5-15	19.25	9.62	10.2	2.1	1.93	0.79	4.6	2.1

Table 3.4-27. Monthly means for chemical and microbiological characteristics of WRS soils. Values are averages for all transects and soil depths sampled during the given month in 1983. Values followed by common letters are not significantly different as tested by ANOVA and Fishers LSD separate tests ($F \leq .05; \alpha \leq .05$).

Variable	Unit	January	April	July	October
Moisture	%	22.5 [a]	17.3 [b]	1.1 [c]	4.1 [b]
pH		8.13 [a]	8.07 [a]	8.12 [a]	7.86 [b]
EC	$mmho/cm^2$	0.24 [a]	0.22 [a]	0.43 [b]	0.28 [a]
Organic Carbon	%	1.09 [a]	1.25 [ab]	1.38 [b]	1.03 [ab]
Total Bacteria	10^6 CFU/g	22.8 [a]	34.8 [b]	3.8 [c]	13.0 [d]
Total Fungi	m hyphae/g	46.5 [a]	96.6 [b]	27.0 [c]	15.2 [d]
Respiration	10^{-4} meq CO_2/g /hr	7.3 [a]	5.9 [b]	1.3 [c]	2.0 [c]
Dehydrogenase	mg formazan/liter	16.0 [a]	8.6 [b]	13.9 [c]	8.6 [b]

Figure 3.4-8. Monthly mean moisture contents for 0-5 cm (O) and 5-15 cm (●) soils. All sites are included. Results for 1981 - 1983 are compared.

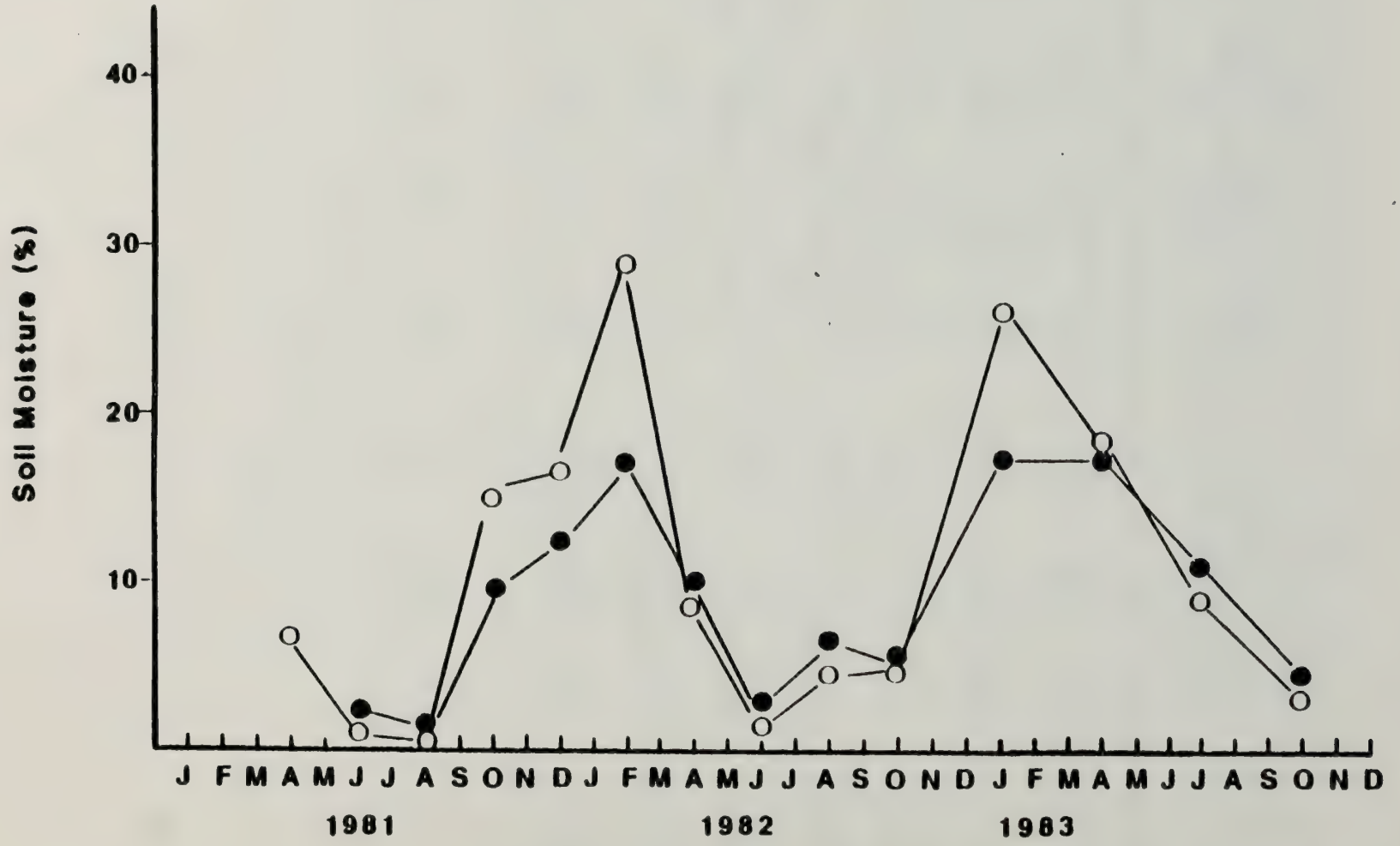


Table 3.4 -28. Yearly summary by site of the soil and microbiological data taken during 1983. Values followed by common superscripts are not significantly different as tested by ANOVA and Fisher's LSD with F $\leq$.01 and $\alpha \leq$.05.

VARIABLE	UNIT	VS1	VS4	VG1	VG2	VG3	VJ1	VJ5	VR1
Moisture	%	13.8^{d}	8.1^{a}	11.6^{c}	10.1^{bc}	10.0^{abc}	11.3^{bc}	9.4^{ab}	15.7^{e}
pH		8.02^{ab}	8.32^{c}	8.01^{ab}	7.98^{ab}	8.03^{ab}	7.94^{a}	8.08^{b}	7.99^{ab}
EC	mmho/cm	0.28^{a}	0.21^{a}	0.22^{a}	0.20^{a}	0.23^{a}	0.22^{a}	0.24^{a}	0.74^{b}
Organic Carbon	%	1.48^{d}	0.83^{a}	1.14^{bc}	0.97^{ab}	0.78^{a}	1.28^{c}	1.13^{bc}	1.91^{e}
Total Bacteria	10^{6}CFu/g	30.1^{bc}	10.5^{a}	18.3^{ab}	13.8^{a}	18.8^{ab}	11.8^{a}	13.9^{a}	31.5^{c}
Total Fungi	m hypae/g	51.5^{bcd}	39.4^{ab}	41.0^{abc}	36.5^{a}	39.3^{ab}	59.3^{d}	50.2^{bcd}	53.3^{cd}
Respiration	10^{-4}meq CO_2/g/hr	4.15^{a}	3.5^{a}	4.5^{a}	3.5^{a}	3.8^{a}	4.0^{a}	3.2^{a}	6.0^{b}
Dehydrogenase	mg formazan/ liter	14.1^{c}	10.4^{a}	11.7^{ab}	12.1^{ab}	11.0^{ab}	12.4^{bc}	11.3^{ab}	11.2^{ab}

the 5-15 cm zones of soils on tract and the difference is significant at $\leq .01$. The slightly lower values of the surface soils may reflect their higher organic matter contents. There were also significant differences in soil pH between transects and sampling dates (Tables 3.4-27, 28). Sites VS4 had a significantly higher pH value than the other seven sites. October samples also had consistently lower pH values than the earlier samples. These results are consistent with those measured in 1981 and 1982 (Figure 3.4-9).

Electrical conductivities of the soils sampled averaged 0.29 ± 0.09 mmhos/cm (all transects, depths, and dates). There were significant differences in EC between sampling dates and sites but not sample depths (Table 3.4-27, 28). Soils from the riparian site (VR1) had the highest EC (.74), presumably reflecting salt accumulation from surface evaporation. July samples were significantly higher than the three other sampling periods tested and higher than any previous sampling since 1981 (Figure 3.4-10).

3.4.8.3 Organic Carbon Organic carbon contents averaged 1.52% in 0-5 cm soils and 0.8% in 5-15 cm soils on the Ua and Ub tracts. These levels were slightly higher in the 0-5 cm soils and lower in the 5-15 cm soils than those measured in 1982. The annual trend in declining organic matter that was noticed in 1982 did not appear this year (Table 3.4-27). The riparian site was again significantly different from most of the upland sites, while site VS1 was also significantly greater than the other upland sites (Table 3.4-28). Soils collected during the summer had significantly higher levels of organic carbon than soils collected during the fall and winter periods.

3.4.8.4 Total Fungi and Bacteria Soil bacteria fluctuated in an annual

Figure 3.4-9. Average pH values for all sites and depths for 1981 - 1983.

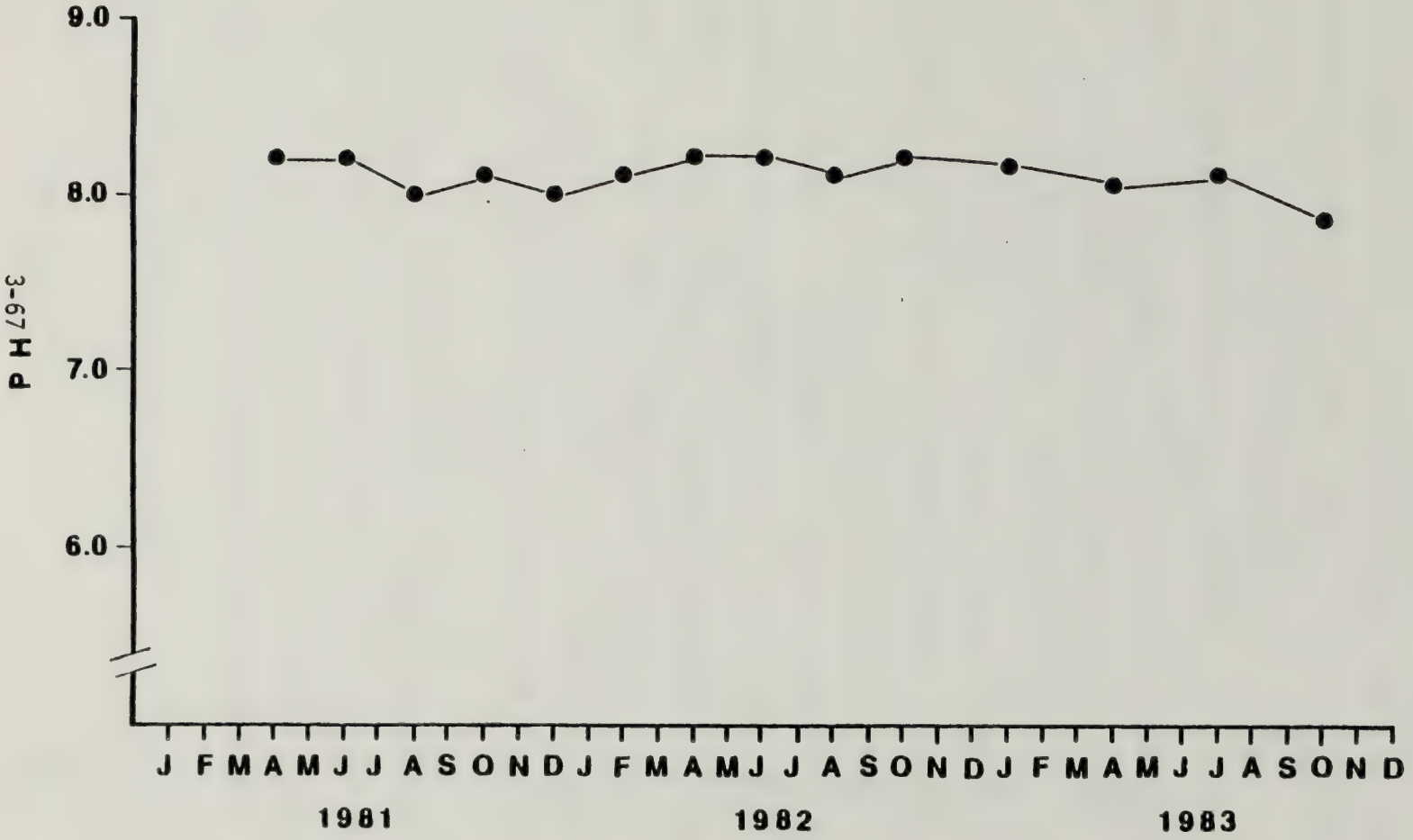
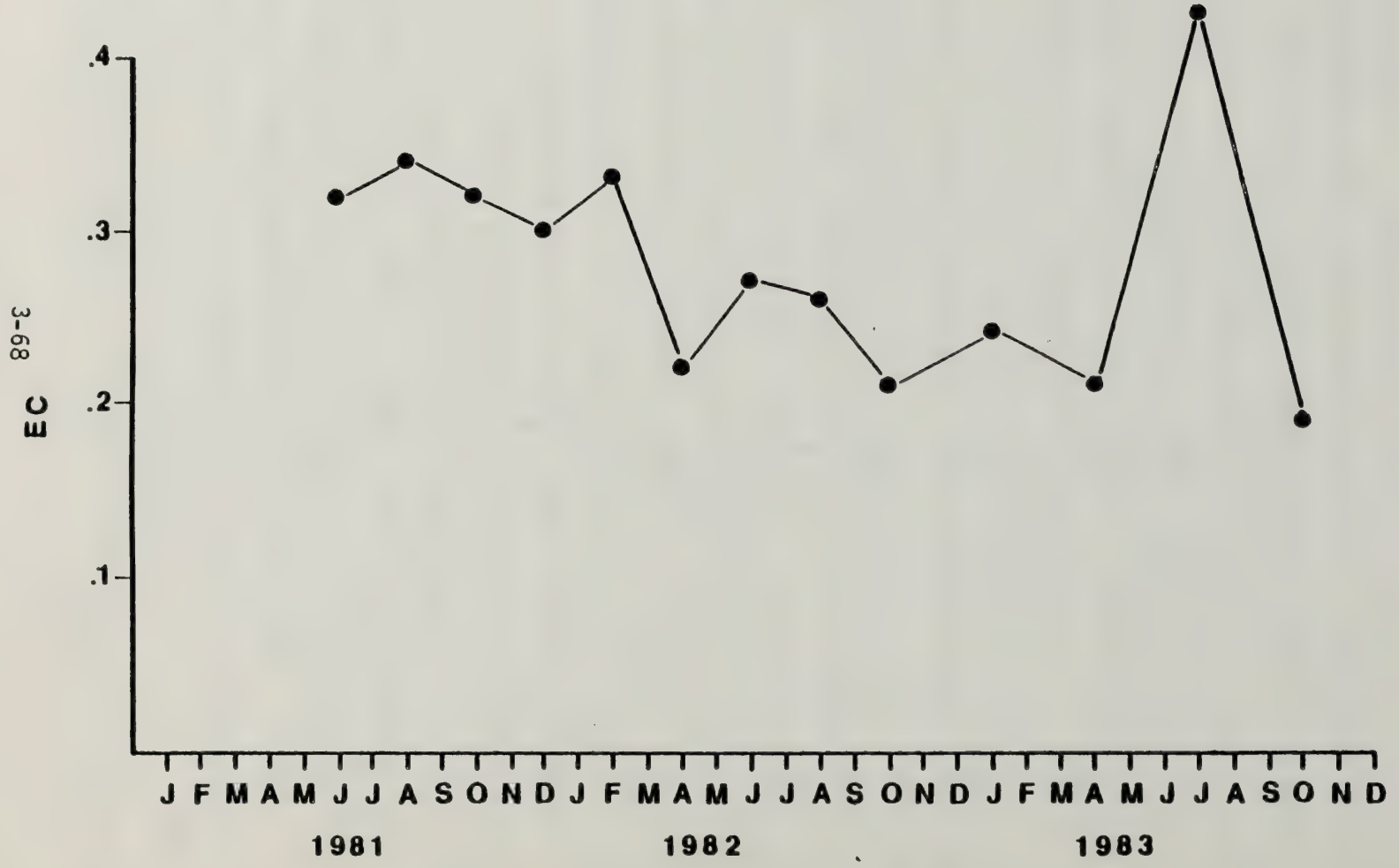


Figure 3.4-10. Average EC values for all sites and all depths for 1981 - 1983.



cycle characterized by a winter-spring peak and a summer low (Figure 3.4-11). In 1983, counts hit a maximum of $34.8 \pm 17.0 \times 10^6$ CFU/g (all sites, all depths) in April and a minimum of $3.8 \pm 1.9 \times 10^6$ CFU/g in July. January and October values fell in the 13-23 $\times 10^6$ CFU/g range (Table 3.4-27). This cycle replicates fairly well the values obtained for 1982 (Figure 3.4-11), however, the top of the winter peak was not sampled since the sampling was changed from February to January. The April sample was also much higher than in 1981 or 1982 as was the case with the soil moisture data. Factors governing these fluctuations will be discussed later. On the average, bacterial counts for subsurface (5-15 cm) soils were 50% lower than counts for surface (0-5 cm) soils, however, the difference decreased during the summer months. Sites differed significantly in bacterial populations with sites VS1 and VR1 having a higher number of bacterial populations than the other six sites (Table 3.4-28).

Fungal populations increased in early 1983 after a general decline from approximately 60 m/g in February 1982 to about 40 m/g in August and October of 1982 (Figure 3.4-12). However, the July and October (1983) samples were very low and retained the generally declining pattern of fungi over the 2.5 years on record.

Subsurface (5-15 cm) populations were consistently higher than surface populations averaging about 20% more. Differences were evident between sites, with the juniper (VJ1 and VJ5) sites and sites VS1 and VR1 supporting generally high subsurface populations of fungi. The sagebrush-greasewood sites had the lowest population of fungi.

3.4.8.5 Total Algae Analysis of the soil algal community on a consistent

Figure 3.4-11.. Yearly cycle of total bacteria for 0-5 cm (O) and 5-15 cm (●) soil depths. All sites are included for 1981 - 1983.

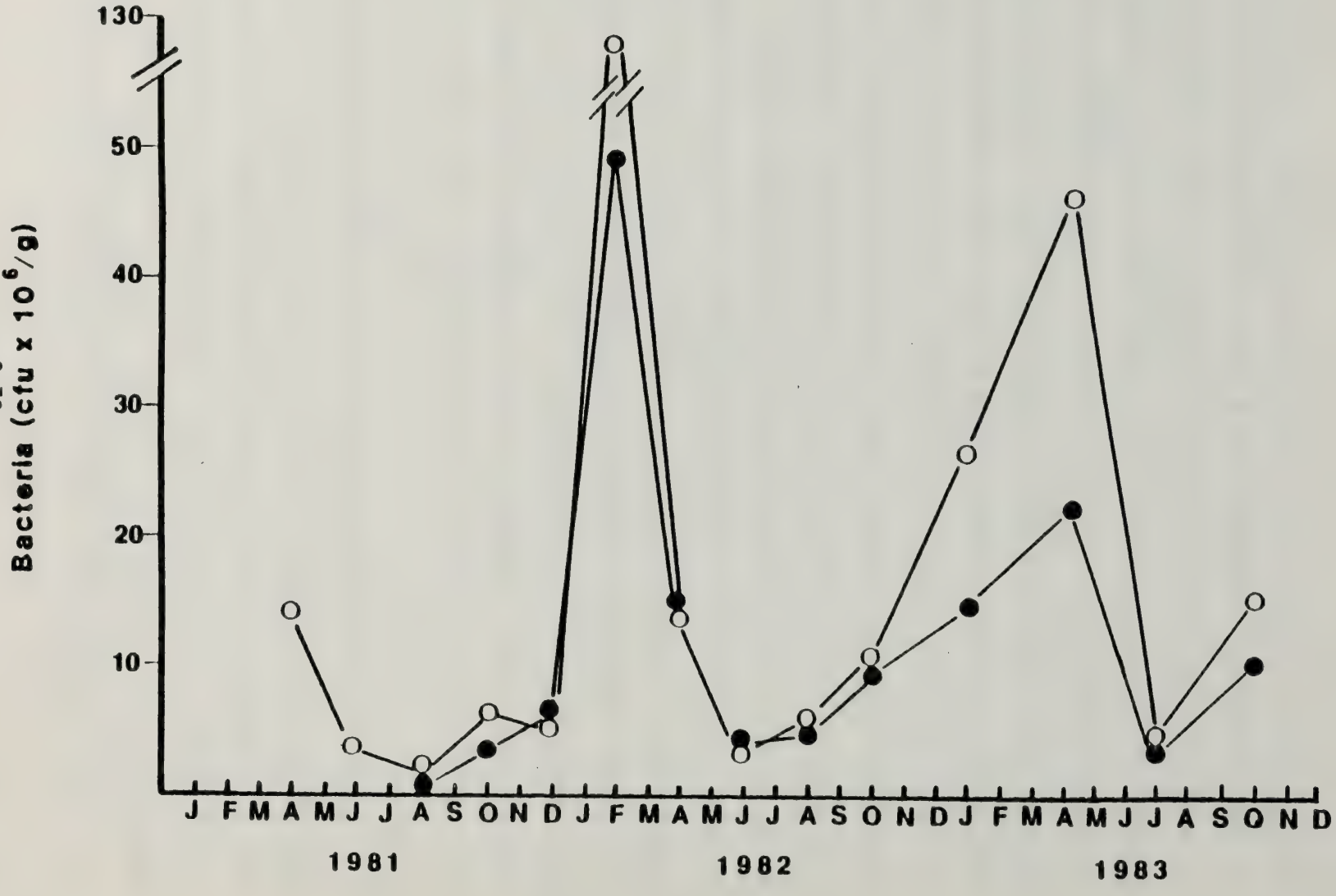
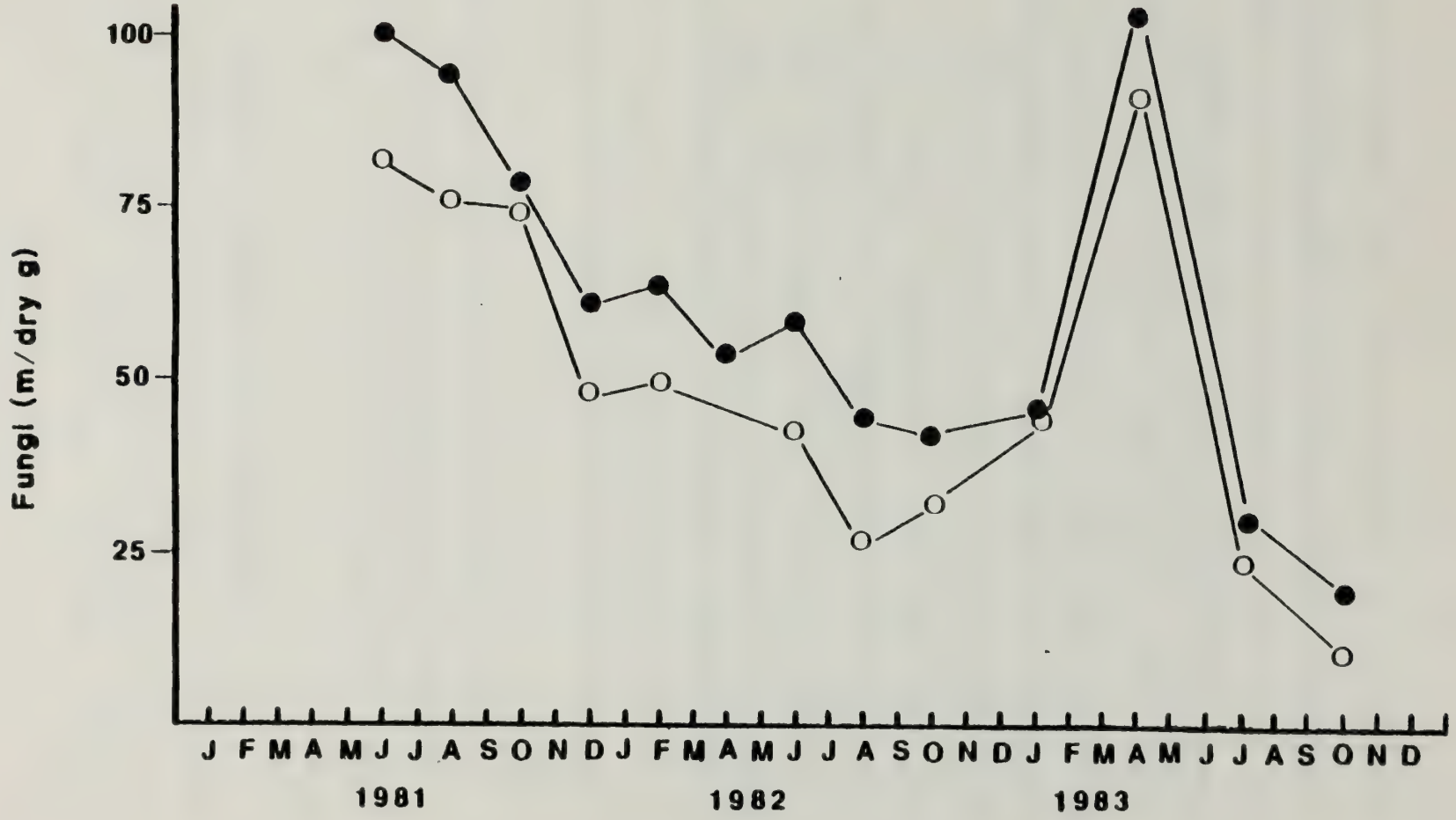


Figure 3.4-12. Monthly mean fungi value for 0-5 cm (O) and 5-15 cm (●) soil depths. All sites are included for 1981 - 1983.



basis was initiated in April of 1983. Soil samples collected at each of the eight sites were analyzed for total filamentous algae, total single-celled algae and total diatoms. The samples were analyzed in April and July using the hemacytometer method (Clark and Durrell, 1965) with fluorescence microscopy (Tchan, 1953). Soil particles blocked the chamber and counts were too low to provide an adequate sample and hence this method was determined to be inadequate and was modified for the October sampling. A counting chamber device was developed at NPI that accomodates the larger sized soil particles and was tested and used for the October soil algae direct counts. Direct algal counts were found to be well within the expected range (Metting, 1981).

Results of the October direct algal counts are presented in Table 3.4-29. Algae were divided into filamentous algae, single celled algae, and diatoms. Since fluorescence microscopy was used all counts were of living material and in the case of diatoms not diatom frustules as is common in other sampling methods. Filamentous algae were so rarely encountered that they were dropped from the analyses.

Seasonal trends and differences between vegetation types will be reported in subsequent quarterly reports as more data is collected. At this point a refined methodology has been developed and will be used in future sampling efforts.

3.4.8.6 Respiration and Dehydrogenase Activities Mean rates of respiration in the soils showed an annual cycle characterized by a January high of 7.3 ± 0.9 meq $CO_2 \times 10^{-4}$/g/ hr and a July low of 1.3 ± 0.1 meq $CO_2 \times 10^{-4}$/g/hr. Surface and subsurface soils followed similar patterns (Table

Table 3.4 -29. Direct algal counts for the October soil samples for eight sites.

Transect Location	Singled Celled Algae #1	#2	#3	$\bar{x}$(S.D.)	Diatoms #1	#2	#3	$\bar{x}$(S.D.)
VG1	625	940	825	797(159)	668	118	707	498(329)
VG2	1375	1570	900	1282(345)	1767	1139	432	1113(668)
VG3	2240	1300	2870	2137(790)	1532	825	2396	1584(787)
VJ1	1450	1728	1690	1623(151)	353	1375	1100	943(529)
VJ5	625	1335	940	967(355)	275	1060	1649	995(689)
VS1	785	275	745	602(284)	275	39	980	431(490)
VS4	1500	2000	940	1480(530)	625	1020	1060	902(240)
VR1	390	705	590	562(159)	471	0	39	170(261)

3.4-27, Figure 3.4-13) although subsurface soils are significantly lower in respiration than surface soil (30%). There are also significant differences in soil respiration between sites with the VR1 site having significantly higher respiration rates than the upland sites (Table 3.4-28).

While respiration values for 1981 also showed an annual cycle of winter highs and summer lows, data for that year was approximately 10-fold higher in magnitude than that recorded in 1982 or 1983. Respiration assays in 1981 were performed by a laboratory at USU. Techniques were similar to those used this year, but we have subsequently learned that samples were typically stored for 4-6 weeks prior to analysis. We suspect this "incubation" period may account for the high respiration results recorded in 1981.

Dehydrogenase activities in the soil sampled showed a six-month cycle in 1983. Mean values (all transects, all depths) hit minimums in April and October of 8.6 mg formazan/liter, (for both) and maximums in January and July of 16 and 14 mg formazan/liter, respectively (Table 3.4-27). This trend was more apparent with the 1981-1982 data particularly since the winter peak was in December in 1981 while in 1982 and 1983 no samples were taken in December. Soils from the two depth intervals behaved similarly, although surface materials consistently showed almost twice the dehydrogenase activity of subsurface materials (Figure 3.4-14) (significant at $F \leq .01$ as tested by ANOVA). There were also differences between sites for dehydrogenase with site VS1 and VJ1 being the two sites with highest values (14.1 and 12.4 mg formazan/liter, respectively) and site VS4 having the lowest (Table 3.4-28).

3.4.8.7 Correlation between Chemical And Microbiological Factors Corre-

Figure 3.4-13. Monthly mean respiration for 0-5 cm (O) and 5-15 (●) soil depth. All sites are included for 1981 - 1983.

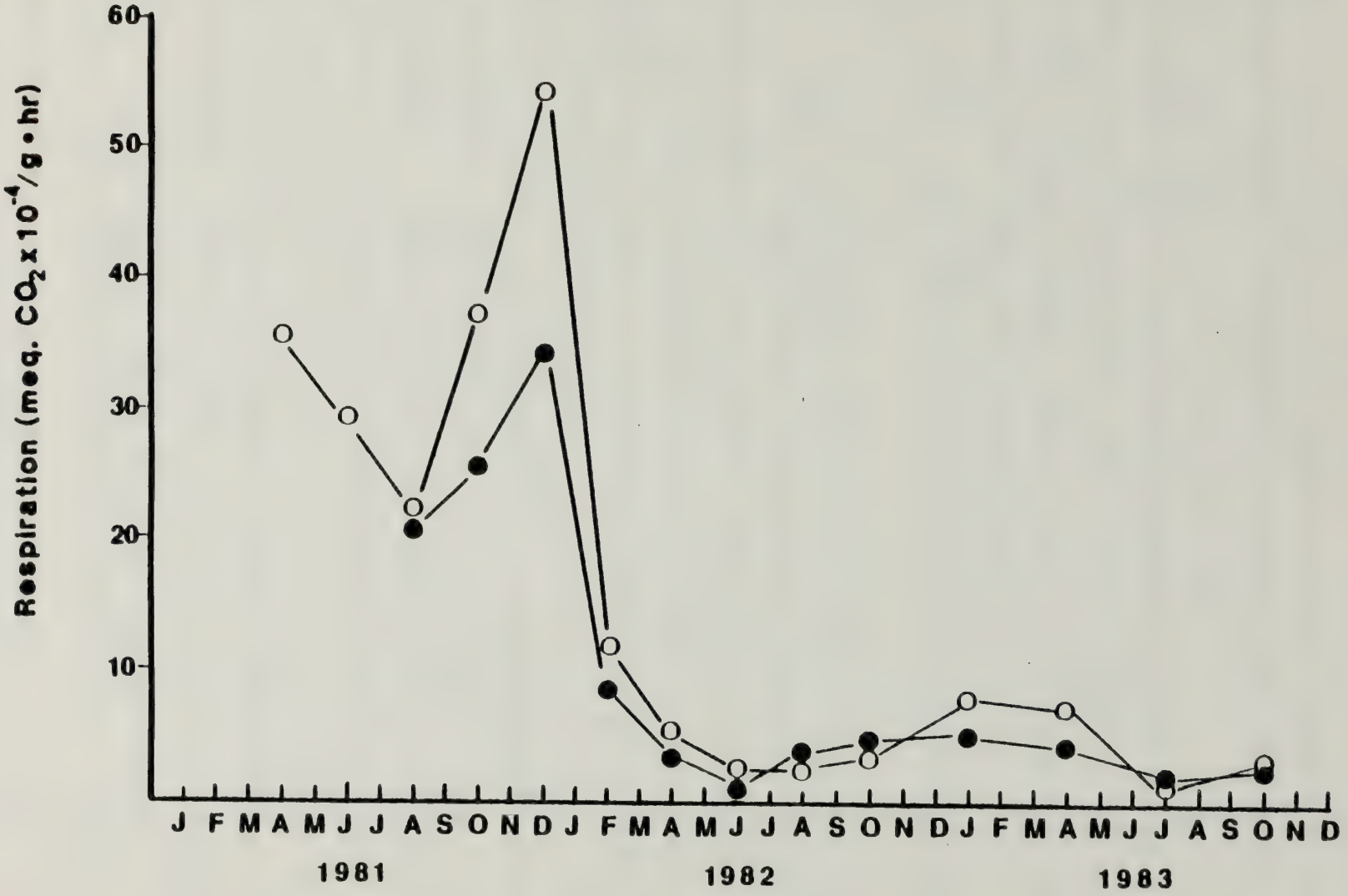
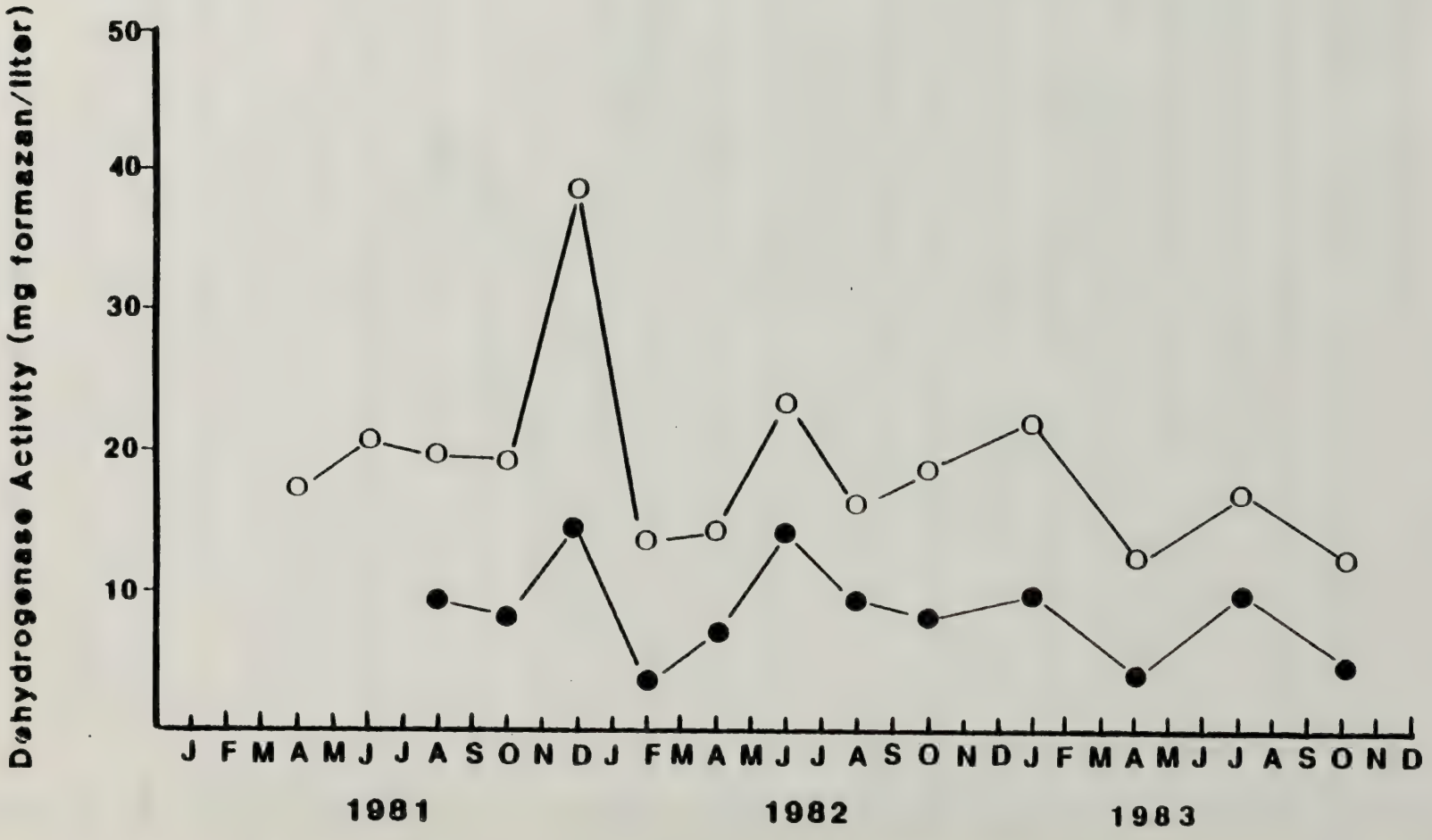


Figure 3.4-14. Monthly mean dehydrogenase activities for 0-5 cm (O) and 5-15 cm (●) soil depths. All sites are included for 1981 - 1983.



lation coefficients linking the eight variables measured for White River soils are given in Table 3.4-30. This analysis includes all samples collected during 1983. Only relationships for which ≤ 0.01 are listed.

Correlation coefficients among chemical parameters are similar to the relationships found in 1981 and 1982. Again, the finer textured soils, with generally higher moisture contents, tended to have lower pH's, higher EC's and higher organic carbon contents (see 1982 final report).

Coefficients linking chemical and microbiological properties showed the following:

1. As expected, high bacterial counts, fungal hyphae lengths, microbial respiration and dehydrogenase levels were associated with relatively moist soils. Water stress typically limits microbial growth activity in arid areas. Dehydrogenase activity, and fungal hyphae lengths which showed weak or opposite relationships in 1982 were both positively correlated with moisture in 1983.
2. Bacterial numbers and activities tend to be positively correlated with organic matter content. Soils that are rich in organic matter tend to support larger and more active microbial populations. Again, this result is expected since soil organic matter is the primary energy source for microbial populations.

Correlations among microbiological parameters indicated strong positive relationships between bacterial counts and respiration, between fungal counts and respiration, and association between respiration and dehydrogenase.

In general, the coefficients given in Table 3.4-30 are low ($\pm$ 0.2-0.5), but

Table 3.4-30. Correlation coefficients linking chemical and microbiological parameters for tracts Ua and Ub soils. All 252 samples collected in 1983 are included in this analyses. Only relationships for which $\alpha \leq 0.01$ are listed.

	Moisture	pH	EC	Organic Carbon	Total Bacteria	Total Fungi	Respiration	Dehdrogenase
Moisture								
pH								
EC								
Organic carbon		-0.29	0.25					
Total Bacteria	0.52			0.24				
Total Fungi	0.54				0.29			
Respiration	0.83			0.32	0.48	0.40		
Dehydrogenase	0.29	0.25		0.49			0.36	

this is not surprising given that all sampling periods, sites, and depth intervals are included. As in 1981 and 1982, correlation coefficients for soils collected from a given depth on a given date were generally higher ($\pm$ 0.4-0.6) but the significance ratings were not different.

Most 1983 results are statistically similar in magnitude to results obtained in 1981 and 1982. Repeating annual cycles in soil moisture, bacterial counts, and respiration are beginning to appear. Most parameters being measured are significantly correlated with one another, and most of the correlations make biological sense. This is evidence that a coherent package of variables have been chosen and that our measurement techniques are sound. As WRSP data is compared with those of others, it is expected that significant cause and effect relationships linking soils with vegetation and wildlife will appear.

3.4.9 Revegetation Success on Disturbed Sites

Revegetation efforts along the highway from Bonanza to the plant site began in the fall of 1982. Areas paralleling the highway were seeded using both hydromulching and drill seeding, and in certain locations transplants were used to revegetate the barren slopes. In June of 1983, four sites were located between Duck Rock and the end of the pavement going south towards the plant site. Sites are representative of conditions and treatments along the access road.

The sites were sampled twice during 1983 to evaluate success. The initial sampling occurred June 6-8, 1983. Density of seedlings were determined at each stand by placing quadrats ($0.25m^2$) along a transect traversing the seeded area and parallel to the road. The distance between quadrats varied with the size of the stand. The number of seedlings, either by lifeform or species where

possible, encountered in each $0.25m^2$ quadrat was recorded. This information was used to assess the revegetation success using a stand rating system described in Vallentine (1974). Survival of transplanted shrubs was also recorded. Results of this initial sample were reported in NPI's Second Quarterly Report (July 1983).

The same sites were resampled in October to determine the survival after the critical summer period. Results of this sampling are reported in Table 3.4-31. Sampling procedures were the same with the exception that the density of seedlings was determined at each stand by placing $0.5m^2$ quadrats along a transect traversing the area selected instead of $0.25m^2$ quadrats.

The average density of all plots on all sites was 9.6 plants/m^2 which would be classified by Vallentine (1974) in the excellent category for seeding success in the Intermountain area. Of the 12 plots sampled, four plots would fall into the excellent category, four into the good category and four into the fair category. Of the 9.6 plants/m^2, 4.1 were grasses and 5.5 were shrubs. The most commonly encountered species was sagebrush (averaging approximately 4 plants/m^2), followed by western wheatgrass (3 plants/m^2) and fourwing saltbush (1 plant/m^2).

The plots were analyzed for differences that may be due to changes in aspect, soil material (cut or fill slopes) and method of seeding. The only significant difference in treatments was between the plots on cut or fill slopes. Plant density averaged 5.5/m^2 on cut slopes and 15.3/m^2 on fill slopes. The high percentage of rock on the cut slopes was probably a major reason for the low density value. There was no difference between east and west aspects or drill seeding and hydroseeding. Drill seeding, however, appeared to favor grasses

Table 3.4 -31. Seedling density on reclaimed areas 1 year after seeding. Data is number of individuals/m^2. Data gathered October 1983.

Species	Site 1 A	B	C	E	Site 2 A	B	C	D	E	Site 3 E	F	Site 4 G
AGSM	1.9	2.5			3.5	2.8	6.8	2.3	1.8	0.4	2.8	11.0
ORHY	0.3	0.5		1.0				0.5	0.5		0.3	1.3
Grass Seedlings		4.5	3.3	1.6								
ARTR	6.3		0.3	0.5	0.8	23.0		9.3	0.3	4.3	2.0	1.0
ATCA	0.4	0.5	0.4	0.1	0.5	1.0	0.3	2.0	1.0		0.8	2.3
ATCO						0.6		0.5		0.5		0.3
ATCU	0.1			0.3								0.5
CHNA	0.5					2.0		0.8		0.5	0.3	1.0
EULA				0.1								
BRTE	3.6		0.1		6.8	4.8		2.5	0.5	1.9	3.0	0.8
KOAM												
MAAF	0.3							0.5		1.2		
HAGL	0.5		0.1	0.5		1.6	0.3	0.5	0.5		0.3	3.5
SAKA	1.9	1.0	0.3	1.4	2.5	0.2	0.5	1.2	1.0	0.3	1.3	0.5
UNKN	0.1			0.1								
Total Seeded	9.5[1]	8.0[2]	4.0[3]	3.6[3]	4.8[3]	29.4[1]	7.1[2]	15.4[1]	3.6[3]	5.7[2]	6.2[2]	17.4[1]

A. Drill seeded, Cut slope, East Aspect
B. Hydroseeded, Fill slope, West Aspect
C. Hydroseeded, Cut slope, West Aspect
D. Hydroseeded, Fill slope, East Aspect
E. Hydroseeded, Cut slope, East Aspect
F. Drill Seeded, Fill slope, West Aspect
G. Drill Seeded, Fill slope, East Aspect

1 Excellent seeding success
2 Good seeding success
3 Fair seeding success

while hydroseeding favored shrubs. This was probably due to the deep burial of the small seeded shrubs characteristic of drill seeding. These treatments may have shown differences in a normal year but 1983 was particularly wet during the initial establishment period (spring).

Transplanted shrubs were also used in the revegetation of the roadside and associated cuts. An initial survey of survival of transplants in June 1983 showed that 83% of the plants were alive at Site 3 (Table 3.4-32). Sagebrush had the best survival (96%) and rabbitbrush had the poorest (50%). A transect in the same area in October showed that significant losses had occurred. The survival of sagebrush had decreased to 36% while no living transplants of fourwing saltbush or shadscale were found. It should be mentioned that October survival was based on the number of plants encountered in the June sample and that the exact area may not have been resampled in October since no permanent markers were established. Each transect was of a consistent size, however, and located as near the same location as possible. In June dead plants were easy to identify, but by October all traces of some plants had disappeared so only an accurate count of living plants was possible. The October overall survival figure of 22% is based on the number of living plants encountered divided by the total number encountered in the June transect. While this figure may not be exact it does reflect the low survivability of transplants that are not protected from herbivores. This was demonstrated in research done at Section 6 and is critical when herbivore populations are high as was the case in 1983.

Table 3.4 -32. Revegetation success of transplanted shrubs at Site 3 along main access road to the plant site.

Species Outplanted	No. Plants Sampled	% Survival-June	% Survival-October*
ARTR	96	96	36
ATCA	22	91	0
ATCO	29	62	0
CHNA	8	50	12
Total		83	22

*No (few) plants were found along the transect although plants were present during the June sampling. October survival is based on the number of living plants occurring on the transect divided by the total number of plants encountered on the June transect. The transect was not permanently marked in June so that data may not be directly applicable to figuring survival for the October sample. However, the sampling area was nearly identical. Losses were probably due to rabbits which can remove all traces of a transplant.

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AQUATIC BIOLOGY

4.0 AQUATIC BIOLOGY

4.1 INTRODUCTION

The 1983 aquatic biology monitoring program was conducted under the direction of Ecosystem Research Institute of Logan, Utah. This program was a continuation of the aquatic biology program which was reinstituted in 1981.

During 1983, data was collected at the three selected cross-stream transects which are located upstream, adjacent to, and downstream of Tracts Ua and Ub. Data was collected through detailed cross-stream transect surveys and included physical, chemical and biological parameters. Data collection followed the program outlined in the Environmental Monitoring Manual (EMM) published by WRSOC in 1982.

Experiments and analyses were conducted in 1983 to define the nature of variability within sampled parameters to determine if cross-stream transects were appropriate for best statistical documentation of riverine conditions. In addition, experiments were undertaken using introduced substrates to increase the sensitivity (reduce variability) of measurement of macroinvertebrate parameters.

The downstream transect (WR27) was discontinued in August 1983. This location underwent large physical changes in 1983 due to high flows and subsequent channel migration. The transect changed physical character from riffle-like to a deep run with small substrate. During 1984, a downstream riffle transect (WR21) which was surveyed in 1981 during the initial stream survey will be activated. This location will replace WR27.

A special study begun in 1982 to document the nature of important metals in the White River system was completed. The results of that study have important implications to the overall WRSP environmental monitoring program. Results of that study are presented in Section 7 "SPECIAL STUDIES" within this report.

Additional special studies were performed during 1983. These will not be discussed in this report. The first of these studies involved an aerial survey of the region north of the White River to define the potential for pollution from other sources to enter the White River in the vicinity of Tracts Ua and Ub. The second special study assembled the historical information collected on fish populations in the White River near Tracts Ua and Ub. This information was used to evaluate the presence of endangered species in this area and to consider the utility of fish for biological monitoring.

The aquatic biology monitoring program is continuing through 1984. Efforts will continue to reduce variability in monitoring parameters and determine the most sensitive parameters and techniques for monitoring. The closure of Taylor's Draw Reservoir in the fall of 1984 will create changes within the river system. The aquatic biology monitoring program will be challenged to document the degree of change and redefine the baseline information for Tracts Ua and Ub.

4.2 PROGRAM SUMMARY

The 1983 aquatic biology monitoring program continued to document the physical, chemical and biological dynamics of the White River near Tracts Ua and Ub. Efforts were undertaken to increase program sensitivity for impact detection. These efforts included experiments to explore the nature of variability within biological parameters and to refine methods for parameter measurement.

During 1983 as in 1982, the White River system was characterized by elevated flows and increased suspended solids (TSS). Discharge levels and TSS were higher than in 1981 or 1982. River habitats were greatly changed in some instances due to the high flows. Transect WR27 below Asphalt Wash was completely changed in character from a shallow riffle to a deep, swift run. This transect was discontinued as a monitoring site in August, 1983.

Water chemistry parameters, particularly nutrients in the forms of nitrogen and phosphorus followed similar patterns with river discharge as in 1981 and 1982. During 1983, however, levels were elevated in comparison to previous years.

The biology of the system responded to the physical influences as in previous years. The high scouring action and reduced light penetration due to increased TSS prevented algal production during most of 1983. 1983 furnished further evidence that the White River is a light-limited system with primary production being limited during much of the year even though sufficient nutrients may be present. Transects WR03 and WR18 exhibited similar production in 1983 while WR27 with increased depth and unstable

substrate did not respond. It will be interesting to note the changes which will occur when Taylor's Draw Reservoir is closed, causing reductions in TSS at the Tracts.

The macroinvertebrate community continued to respond to discharge. During high flow periods, numbers and biomass were depressed. During lower flows with increased algal production, numbers and biomass of macroinvertebrates increased. 1983 macroinvertebrate production was higher than in 1982. Transect WR27 numbers and biomass decreased to near zero following upper basin runoff while WR03 and WR18 numbers and biomass increased.

Past problems with measurement of leafpack decomposition were addressed during 1983. Problems with siltation were effectively reduced using a new leafpack arrangement. Leafpack data collected in 1983 for which temperature data were available fit the previously developed relationship between degree days and leafpack weight loss.

Comparisons of biological parameters for control and treatment sites showed that chlorophyll a, macroinvertebrate numbers and biomass were not significantly different between transects WR03 and WR18. WR27 was different from WR03 and WR18 for the three parameters. These analyses showed that WR03 (control) and WR18 (treatment) sites were responding similarly.

Experiments were conducted to investigate the relative variability of estimates of chlorophyll and macroinvertebrate parameters from data collected at points along transects as well as at single locations. Both macroinvertebrate parameters showed some reduction in coefficient of variation (c.v.) when estimated at a single location. Chlorophyll a values

increased, but not significantly, when taken at a single location. The results of these analyses suggest that there is little difference in the variance of estimates between the two sampling methods. This is probably due to small differences in overall habitat gradient across the stream to that at single points.

Another set of experiments was conducted using controlled substrates for macroinvertebrate sampling. The variability of numbers and biomass found in substrate baskets was lower than variability across transects. Thus, substrate baskets appear to offer advantages over ambient stream sampling by reducing variability inherent in conventional stream sampling techniques.

A special study was begun in 1982 to document the nature of selected heavy metals in the White River ecosystem. The results of this study are presented in Section 7.2 of this report.

4.3 PROGRAM DESCRIPTION

This section discusses aquatic biology program objectives and provides a summary of important 1983 program features including the quality control program.

4.3.1 1983 Monitoring Program

The Environmental Monitoring Manual (WRSOC 1982) established the aquatic biology monitoring program in its initial form. Long-term sample sites were delineated at six transect locations in the White River. These were riffle transects WR03, WR18, WR27 and pool transects WR05, WR20 and WR29. These sites were selected from twenty-nine transects surveyed in the White River and nine in Evacuation Creek during an initial strem survey in 1981. See Figure 4.4-1 for transect locations.

At the end of 1982 sampling was discontinued on the pool transects due to high variability in biological parameters when compared to riffles. During 1983, all efforts were focused on the three riffle transects. The downstream transect, WR27, changed in character from a riffle to a pool or run-type habitat. This destroyed the comparability of the location with the upstream riffle transects. Sampling at transect WR27 was discontinued after August, 1983. Another riffle transect (WR21) located during the 1981 initial survey will be reactivated as the downstream monitoring site in 1984.

The EMM delineates three levels of monitoring parameters: operational, potential and contingency. These categories were created to provide flexibility in program design. As parameters are adequately categorized or determined to be of low value for monitoring they may be moved from

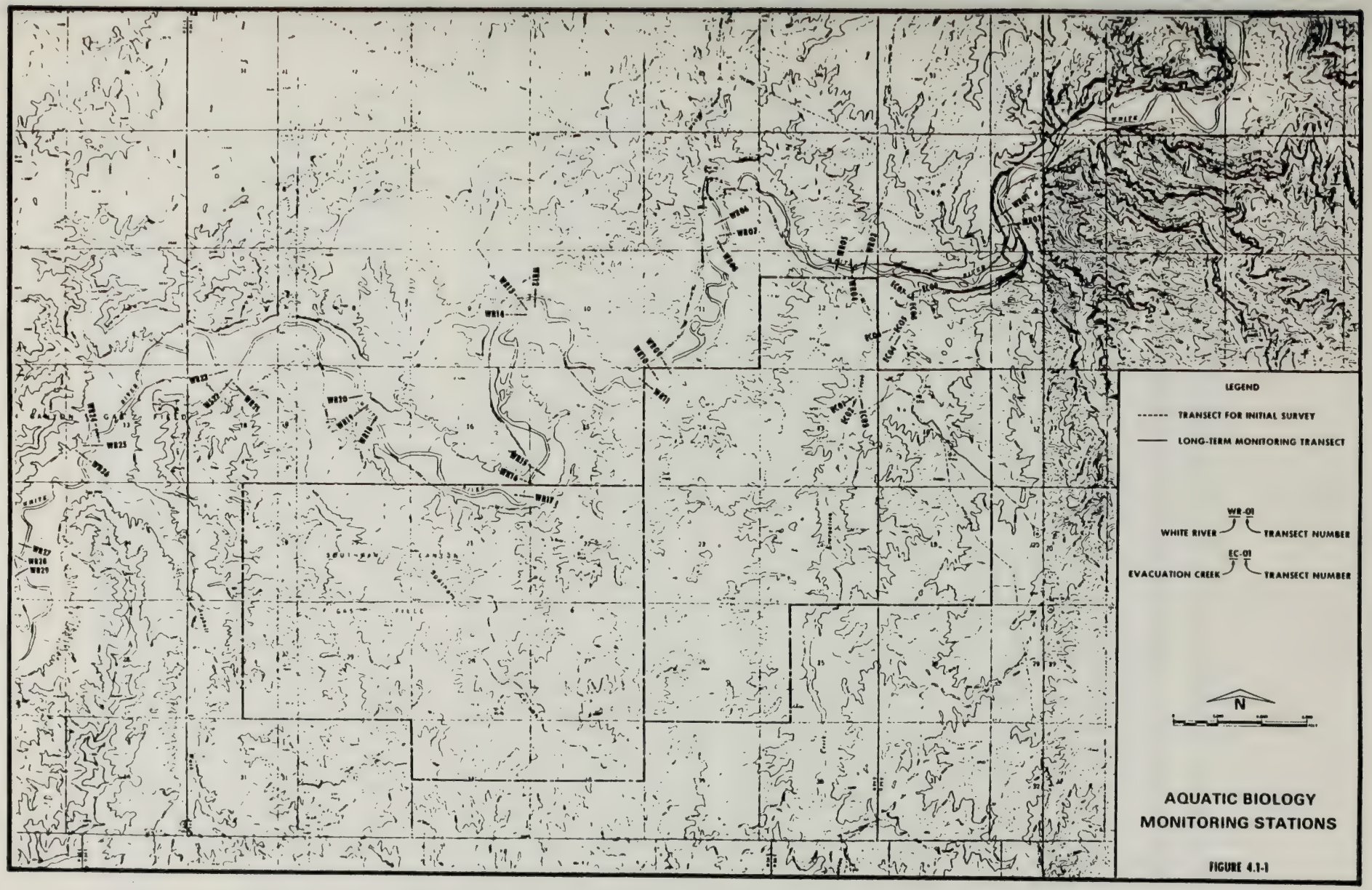

Figure 4.3-1. Location of aquatic biology transects in the White River and Evacuation Creek. WR03, WR18 and WR27 were monitoring sites used during 1983.

operational to contingency categories. Those potential or contingency parameters determined useful for monitoring may become operational.

Two sets of parameters were changed in status during 1983. Periphyton taxonomic characteristics including species richness, species biomass, community biomass, density and diversity were moved from operational to contingency status. This change was made due to the high variability of these measures of the periphyton community. Many additional sample replicates would be necessary to describe the taxonomy of the periphyton community in a statistically valid manner. At the present time this does not appear to be a cost-effective option. In addition, measurement of drifting insects was moved from the potential to the contingency category.

Production-respiration studies using the developing technology of P/R chambers suffered from a series of problems during 1983 which resulted in little data being collected. The most serious problem was a lightning strike which disabled all the electronics in the P/R system. This caused several month's delay in experimentation. The system is operating at this time with several experiments already completed in 1984. No results are presented in this report.

The long-term program described in the EMM has three major objectives :

- To gather data which describes the aquatic ecosystem in sufficient detail to allow assessment of natural or project-related change.

- To organize data collection and analysis using a conceptual view of the ecosystem to determine the cause or pathway of these changes.

- To assess the effectiveness of mitigation or reclamation measures.

During 1983, in addition to routine collection of monitoring data to continue the necessary aquatic ecosystem description, two major experimental efforts were undertaken. These experiments were directed towards refining the sensitivity of monitoring parameters.

The first of these involved collecting additional samples along monitoring transects to evaluate the nature of variability inherent to monitoring parameters within different locations along transects. It was felt the output of these experiments might lead to sample stratification within areas of least variability.

The second effort involved the use of substrate baskets containing cobble-sized substrate at a single location on WR18. The goal of this experiment was to determine if variability at a single location could be reduced by introduction of replicate uniform substrates. The results of this and the previously described variability experiment are discussed in Section 4.4.

4.3.2 Quality Control Program

Three aspects of the aquatic biology quality control program for 1983 are discussed in this section. These are (1) water quality, (2) biological, and (3) equipment calibration.

4.3.2.1 Water Quality The ERI water quality control program has been in operation for one year. Utah State Department of Health and EPA certification requirements have successfully been fulfilled. The water quality control program consists of two analytical elements. These are daily precision and accuracy checks and quarterly audit samples.

A. Precision and Accuracy Every year for each chemical water analysis, seven replicates each must be run for precision and accuracy in accordance with EPA standards. Mean values, standard deviations, relative standard deviations (RSD), percent recovery and relative error are calculated. Percent deviation from the average and percent relative error from daily precision and accuracy, respectively, are compared with yearly compiled data. Daily precision and accuracy values must fall within ±2 relative standard deviations[1] of the yearly compiled data.

For this report relative standard deviations were calculated from EPA audit samples and a regression relationship was used to find RSD for different concentration levels. This was necessitated by the lack of historic compiled data for the ERI lab. These values are approximate but there are no specific guidelines established which can be followed. As ERI builds its compiled data base, an attempt will be made to develop and maintain stricter confidence intervals than EPA requires. Technicians will

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[1] Within the last year, EPA has changed the minimum acceptable levels from ±3 relative standard deviations to ±2 relative standard deviations.

strive to stay within in-house guidelines and use the wider EPA values as minimum acceptable limits.

Daily precision and accuracy checks were performed on all water quality parameters measured for the WRSP. These include ammonia, nitrate, nitrite, orthophosphate, total dissolved phosphorus, total phosphorus, total dissolved solids, and specific conductance. Data for a single parameter, ammonia, are shown in Table 4.3-1 as an example. Tables for all parameters are available but were considered too lengthy for inclusion in this report. All parameters fell within acceptable guidelines.

Precision and accuracy from other projects analyzed with the White River water chemistries are noted with an asterisk (*). Precision shows the mean ($\bar{x}$) of the duplicates and the percent deviation from the mean value. Accuracy includes theoretical (true) spikes, experimental (analyzed) spikes and percent relative error. Percent deviation from the average and percent relative error can then be compared with calculated EPA RSD and +2 RSD.

The analysis from two sample sets taken during the year did not meet guidelines. These were for total suspended solids and total phosphorus. Both samples were collected during sample dates when the White River was very turbid. Due to the high sediment content, it was difficult pouring a well-mixed sample, resulting in large variation among duplicates and spikes. The problem was remedied by continual mechanical mixing while withdrawing a sample aliquot. Large quantities of coarse particulate organic matter also made it difficult to homogenize the sample because of the nature of the material. It was necessary to break this material up into smaller particles in order to thoroughly blend the sample and obtain more uniform duplicates.

Table 4.3-1. Daily quality control results for ammonia analyses for the 1983 aquatic monitoring program.

Date	Log #	Precision $\bar{x}$ of Dup	Precision %(1) Dev Ave	Accuracy Th-Sp	Accuracy Ex-Sp	Relative Error(2) (%)	Calculated Relative Standard Deviation From EPA	Acceptable Within ± 2 RSD
830113	249-2105W	50	14.0	86.54	77.48	-10.5	16.72	33.44
830227	317-2620W	118	0.85	151.92	149.76	-1.42	14.42	28.84
8303	300-2455W*	108	2.78	142.31	156.52	+9.99	14.76	29.52
8303	304-2472W*	131	0	164.42	167.96	+2.15	13.98	27.96
830602	490-3059W	47.5	3.16	84.13	88.4	+5.1	16.81	33.62
830706	583-3416W	32.5	1.54	69.71	75.4	+8.16	17.31	34.62
830803	646-3552W	25.5	1.96	63.0	66.04	+4.83	17.55	35.10
830830	761-3878W	50.5	2.97	87.02	92.56	+6.37	16.70	33.4
831106	062-4640W	31.5	7.9	68.75	60.84	-11.51	17.35	34.7
8312	088-4906W*	6	33.33	44.23	44.2	-.07	18.21	36.42

(1) % deviation from average $= \left(\frac{x_i - \bar{x}}{\bar{x}} \right) \times 100$

(2) % relative error $= \left(\frac{\text{experimental spike} - \text{theoretical spike}}{\text{theoretical spike}} \right) \times 100$

* Q.C. from other projects run with White River samples.

These techniques will be employed as the need arises.

B. Quarterly Audit Quarterly audit samples obtained from EPA continued to be used for quality control during 1983. Results of analyses for first quarter WRSP parameters are shown in Table 4.3-2. Results for all quarters are available but too lengthy for inclusion in this report. All audit sample analyses fell within acceptable guidelines.

4.3.2.2 Invertebrate Sample Processing Processing of invertebrate samples posed problems again during 1983. The original goal of recovering 85% of numbers and 95% of biomass was not attained. Based upon all quality control samples reprocessed, 70% of numbers and 78% of biomass was recovered during initial one-time processing (hand-picking of invertebrates from debris and algae present in sample). Approximately one-third of the samples with low recovery were repicked, bringing the averages to 79% of numbers recovered and 85% of biomass recovered. These recoveries approximate those attained during 1982.

Possible explanations for the low figures are (1) the inclusion of samples from areas other than the White River with high amounts of filamentous algae and organic debris present, (2) new personnel, and (3) use of rose bengal dye conditioned sample processors to select only red-stained invertebrates, thus missing those not stained.

During 1984, quality control for macroinvertebrates will be changed to require one-third of all samples to be repicked. This will be performed each month on the current month's samples. Whenever recovery of total numbers

Table 4.3-2. First quarter results of EPA audit samples for 1983.

Parameter	ERI Value	EPA Value	$\bar{x}$	S	95% CI
Specific Conductance (umhos/cm)	110	125	123	7.9	107-139
	439	479	478	25.5	427-529
pH (units)	7.5	7.4	7.4	0.14	7.1-7.7
	8.5	8.6	8.7	0.15	8.4-9.0
Ammonia (mg/l)	0.146	0.15	0.15	0.02	.0.11-0.19
	1.418	1.52	1.52	0.09	1.34-1.70
Nitrate (mg/l)	0.220	0.18	0.18	0.02	0.14-0.22
	1.60	1.61	1.60	0.08	1.44-1.76
Orthophosphate (mg/l)	0.034	0.04	0.04	0.01	0.02-0.06
	0.264	0.27	0.27	0.01	0.25-0.29
Total Phosphorus (mg/l)	0.131	0.14	0.15	0.05	0.05-0.25
	1.064	1.04	1.06	0.06	0.94-1.18
Total Suspended Solids (mg/l)	32.0	29.1	29.1	2.4	24.3-33.9
	157.0	156	156	6.7	143-169
	550.0	534	534	21	492-576
Total Dissolved Solids (mg/l)	449.0	456	456	18	420-492
	298.0	300	300	20	260-340
	155.0	167	167	24	119-215

drops below 85%, all samples from that month will be reprocessed. In 1984, the target of 85% recovery in numbers and 95% recovery in biomass will be attained.

It should be noted that lower percentages of recovery result in higher variability in the data. Since reduction of sample variability is necessary to increase program sensitivity it is imperative that this source of variability be reduced.

4.3.2.3 Equipment Calibration All instruments are routinely calibrated. Those requiring factory calibration are returned to the factory. Other equipment used to quantitatively collect samples may not be calibrated nor its performance characteristics known. One such example is the ERI standard drift net (Radant 1983) for collection of organic matter drifting downstream. In order to arrive at better quantitative estimates of the amount of drifting organic matter per unit volume of river flow, a series of experiments was undertaken during 1983.

These experiments were performed during early August in the White River, Utah during a period of high organic loading and in the Colorado River near Parachute, Colorado during a moderate organic loading regime. These experiments included time periods up to 30 minutes in duration in both slow and fast areas.

Figure 4.3-2a shows the pattern of decline in velocity at the net entrance as a function of time, initial velocity regime and organic loading regime. In the moderate organic regime of the Colorado River, velocity declined in a linear manner over a 30-minute period in both slow and fast

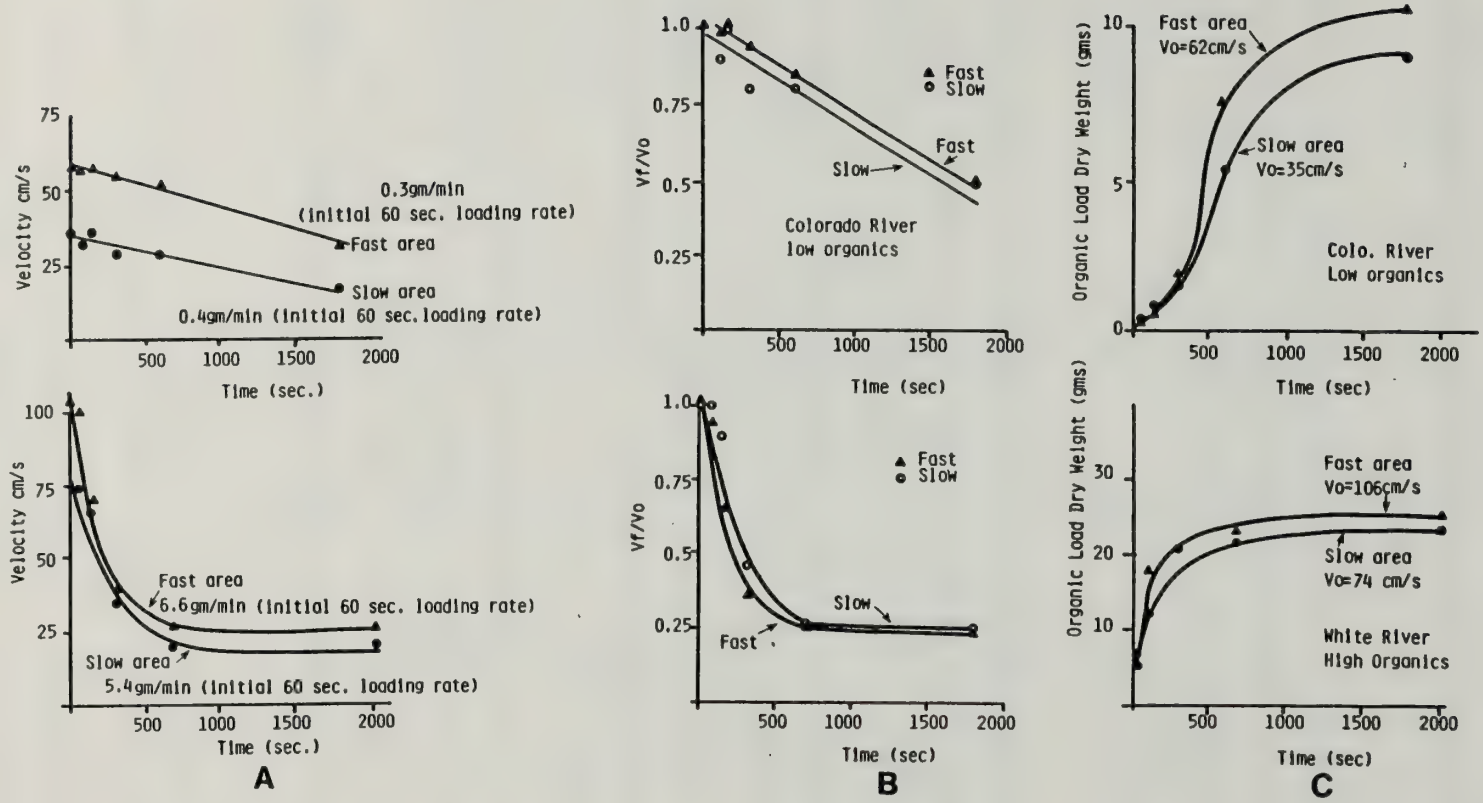

Figure 4.3-2. Velocity, final velocity/initial velocity and organic load accumulation for ERI standard drift nets in areas of low and high velocity and in two different loading regimes.

areas. In the higher loading regime of the White River, the nets saturated at about 10 minutes. The decaying portion of these curves could be described by exponential or linear approximations.

Figure 4.3-2b shows the relationships of final velocity to initial velocity as V_f/V_o between areas of slow and fast velocity and in areas of different organic regimes. In the Colorado River, during 30-minute experiments, V_f/V_o exhibited purely linear form with the ratio declining to 0.5 at 30 minutes. In the higher organic regime of the White River this approximately linear decay in V_f/V_o reached 0.25 at 10 minutes, at which time the nets were saturated and could accumulate no more material. These figures imply that an assumption of linear velocity decreasing with time could be applied over all ranges of conditions to a final V_f/V_o of ≥ 0.25.

Figure 4.3-2c shows the accumulation of organic matter (dry weight) as a function of time in these experiments. From the White River data it was apparent that the ERI nets saturate at about 25 grams dry weight. In the Colorado River experiments a level of approximately 10 grams was reached after 30 minutes, a value well below saturation.

This information can now be used to calculate total volume of water passing through the nets given V_f and V_o within limits of $V_f \geq 0.25\ V_o$ using an assumption of linearity. Total water volume through the nets then becomes:

$$Q = \left(\frac{V_f + V_o}{2} \right) \times \text{Net Opening Area} \times \text{Time}$$

Q = water volume, m^3

The organic load (drift) in the river can then be expressed as a function of water volume:

$$\text{Organic Load } \left({}^{gm}/_{m3} \right) = \frac{\text{Drift (gm)}}{Q}$$

4.4 PROGRAM RESULTS AND ANALYSIS

This section will discuss the results of physical, chemical and biological data collection in the aquatic biology monitoring program during 1983. These results will be compared to previous years. The results of special studies to document the nature of variability in some aquatic biology parameters, the use of introduced substrates for macroinvertebrate sampling and a heavy metals study will be presented.

4.4.1 The Physical Environment

During 1983, the White River experienced higher flows than in the prior two years of the aquatic biology monitoring program. These elevated flows subjected the aquatic habitat to large geomorphic forces which resulted in changes to aquatic habitats. These changes are discussed in the following paragraphs.

Due to higher than normal winter precipitation in the form of snow, upper basin runoff during June, 1983 peaked at nearly 5,500 cfs (Figure 4.4-1). This peak was double that experienced in 1981 and 1982. Following upper basin runoff, flows remained high during much of the remainder of the year. This made sampling for aquatic biology parameters very difficult.

The unusually high upper basin runoff eroded channels and banks and generally changed the morphology and substrate characteristics of many river habitats. Cross-section profiles of the three riffle transects used in the aquatic biology monitoring program are presented in Figure 4.4-2. In this figure, profiles for April, 1982 are presented along with profiles for April and August, 1983 for comparison.

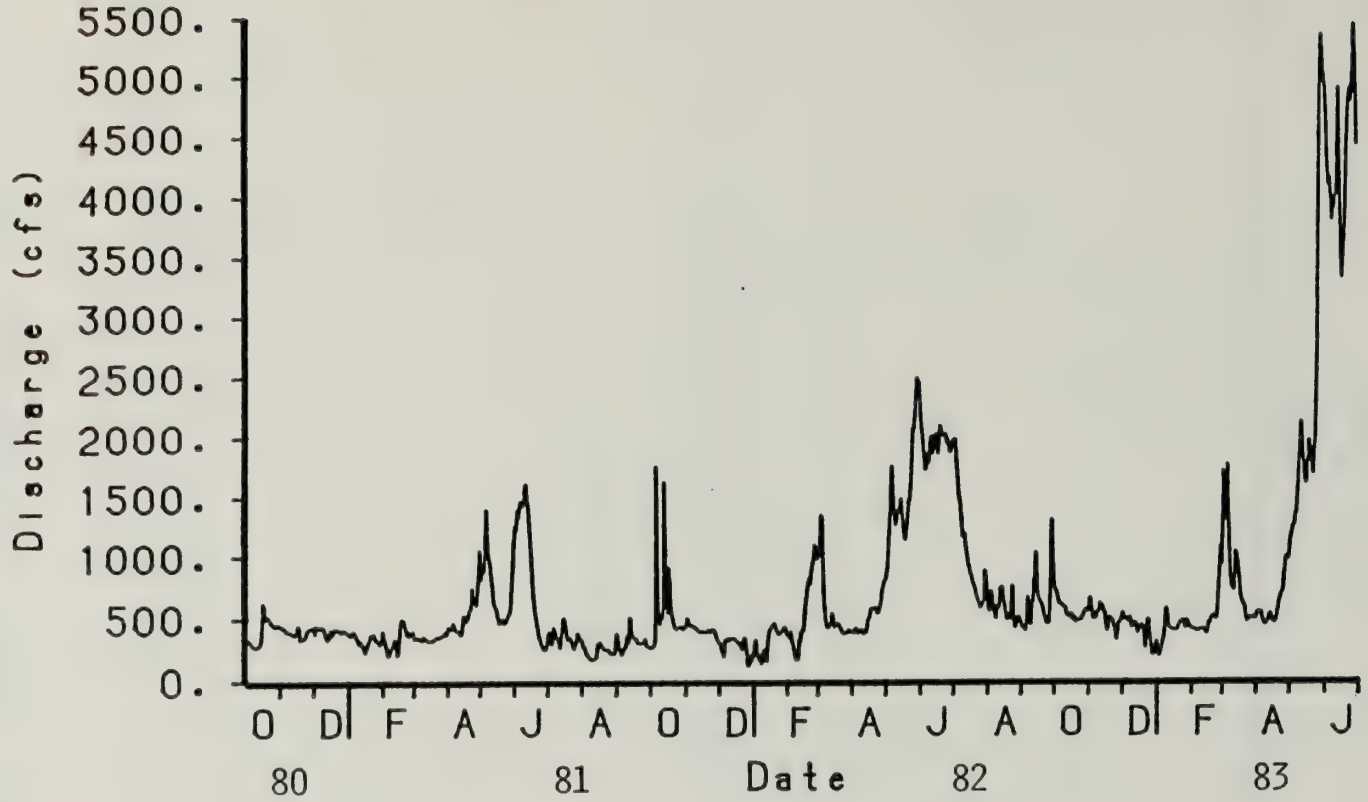

Figure 4.4-1. Discharge in the White River near Asphalt Wash at Station 6700 between October, 1980 and June, 1983. Data from VTN.

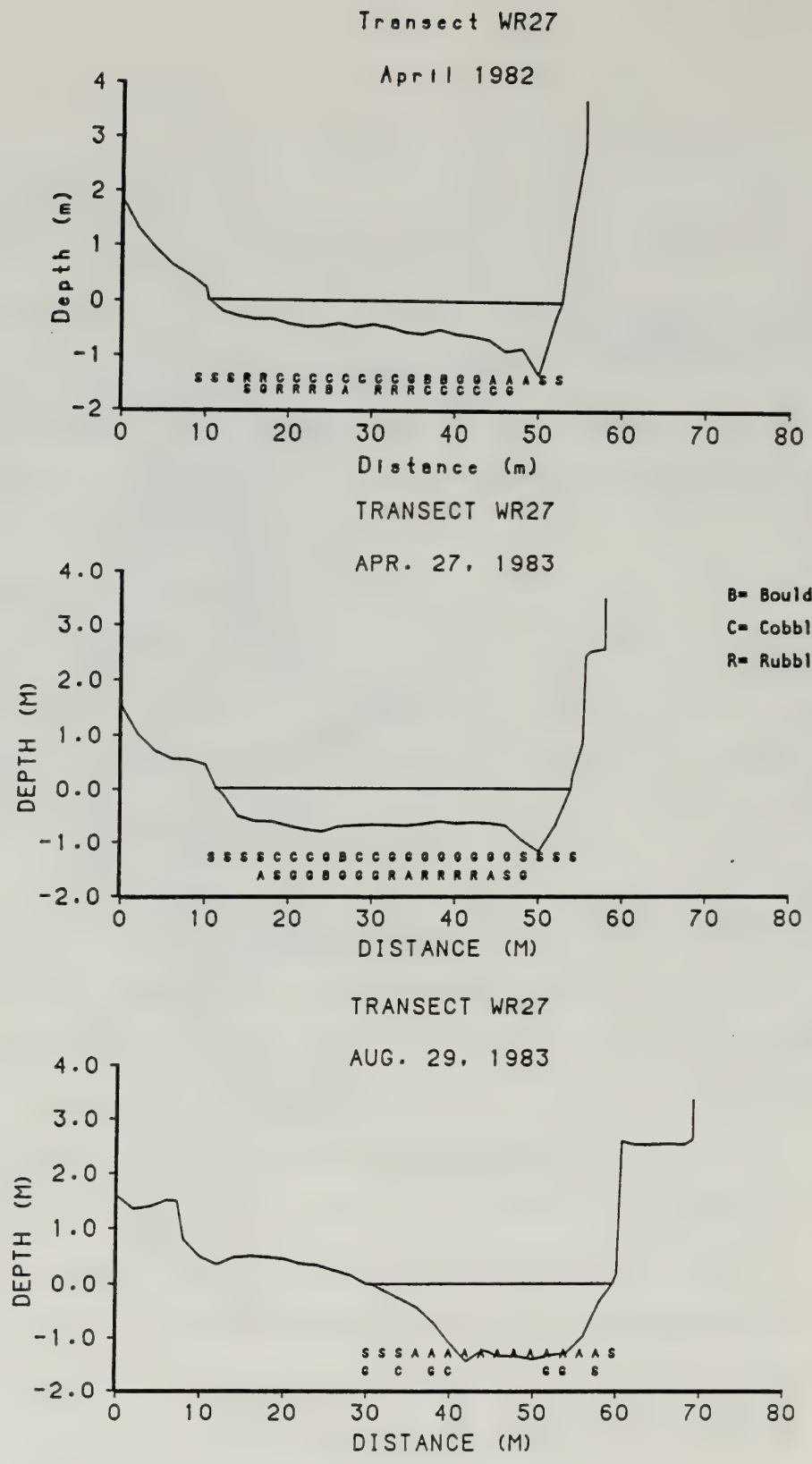

Figure 4.4-2a. Cross-section profiles of White River Transect WR27. April, 1982 is compared to April and August, 1983.

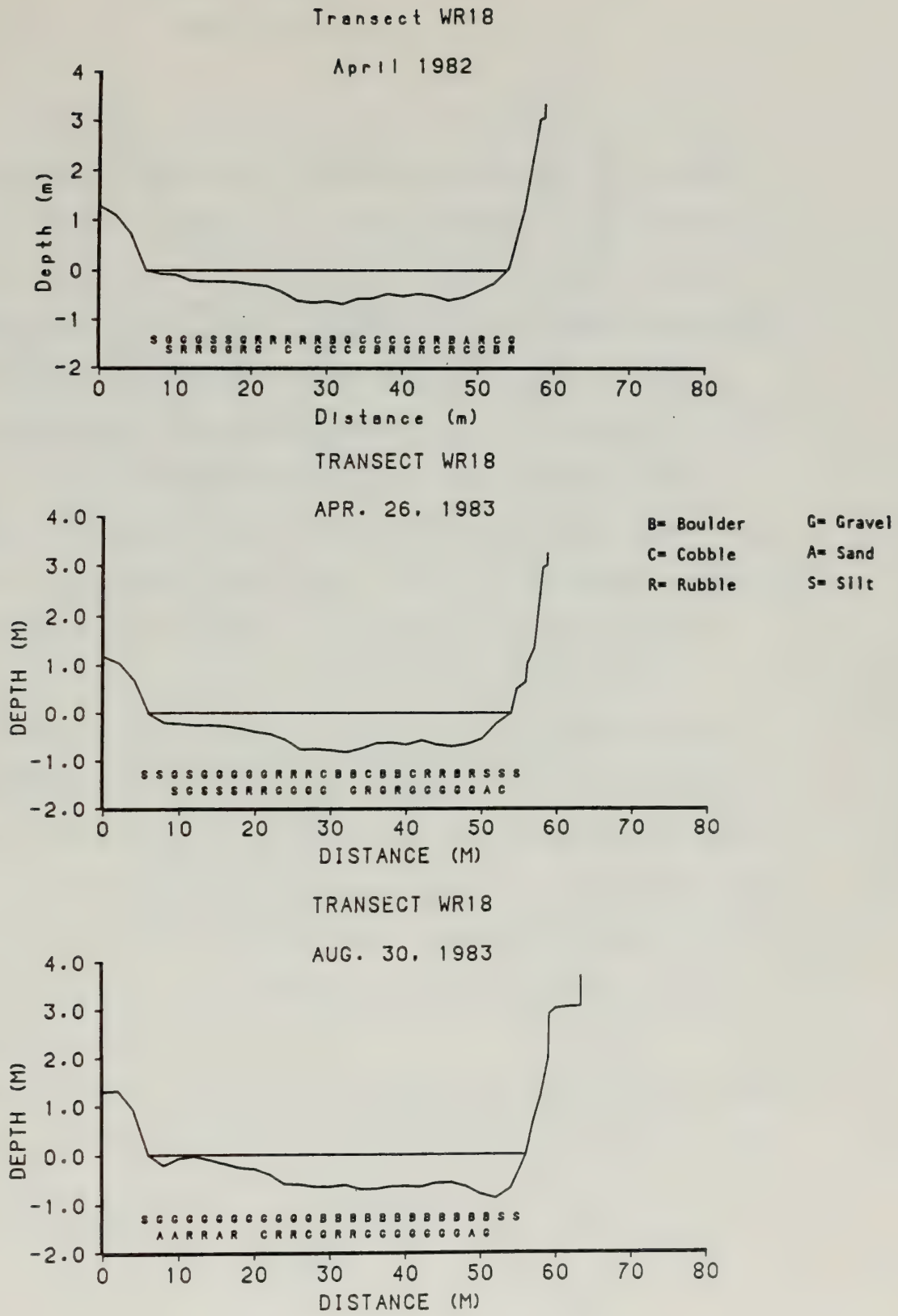

Figure 4.4-2b. Cross-section profiles of White River Transect WR18. April, 1982 is compared to April and August, 1983.

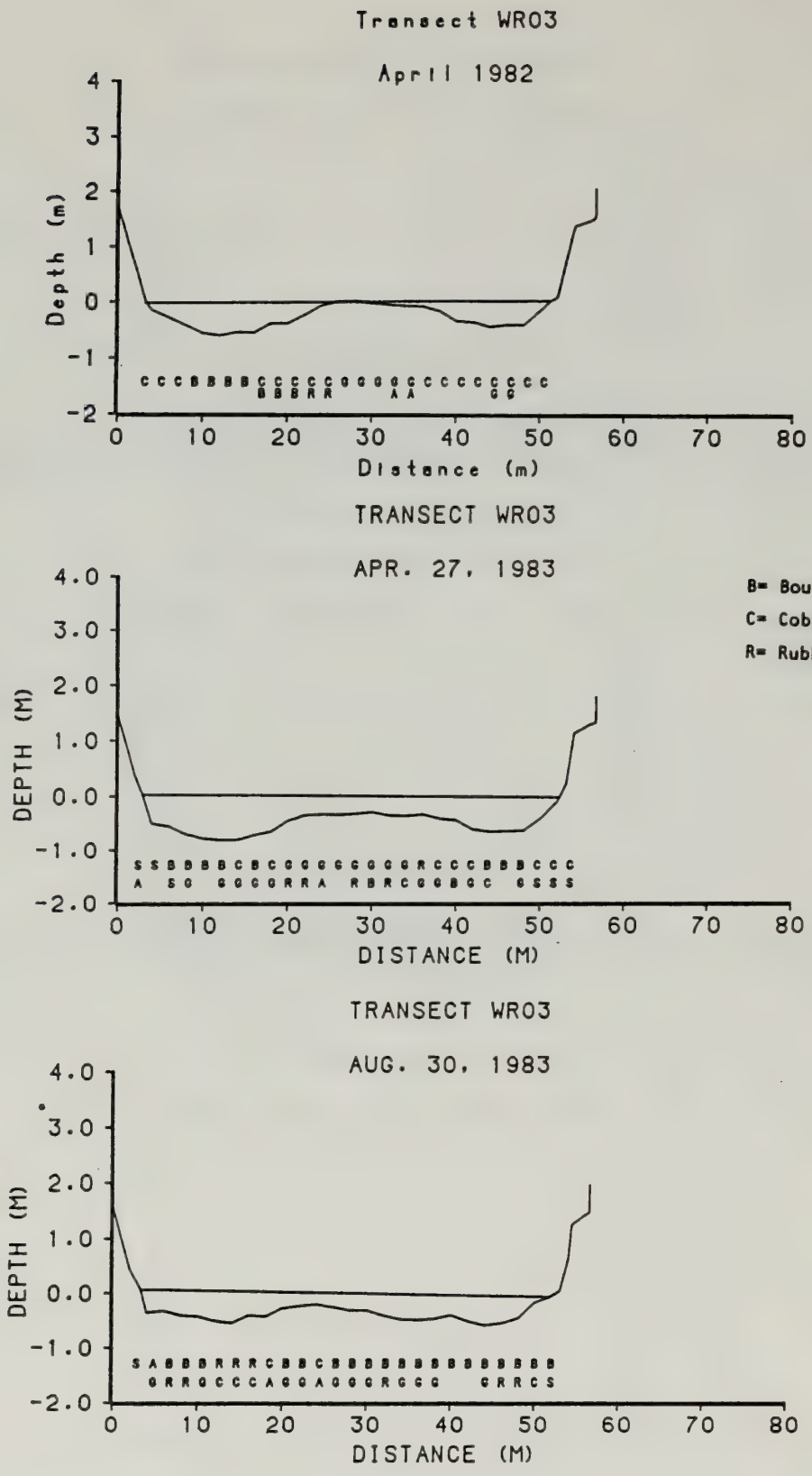

Figure 4.4-2c. Cross-section profiles of White River Transect WR03. April, 1982 is compared to April and August, 1983.

Transects WR03 and WR18 occupy relatively stable positions in the overall channel meander. They both lie within straight channel sections. Transect WR27 was in a bend with no control structure to prevent channel migration within the alluvial plain. The high flows of 1983 eroded the beds of WR03 and WR18 but created little lateral movement. Transect WR27 experienced large changes in channel shape and position, migrating approximately 10 meters laterally during upper basin runoff of 1983.

Comparisons of transect width, depth and velocity for the years 1981, 1982 and 1983 are presented in Table 4.4-1. All the data reflect a year of increased discharge. Mean substrate composition of the transects are presented in Table 4.4-2.

Transect WR03 average width of wetted area and average depth were greater in 1983 than in previous years. Average velocity during 1983 was lower than in previous years due to the erosion of a midchannel bar which resulted in increased channel cross-sectional area. The river channel has not changed in overall width. Mean substrate composition along this transect continued to be diverse and was dominated by boulder and cobble size fractions (Table 4.4-2).

Transect WR18 average width of wetted area, depth and velocity did not change markedly from those measured in 1982. The largest change occurred near the north shore (meter 54) where noticeable downward erosion occurred (Figure 4.4-2). Substrate composition remained diverse with relatively equal proportions of boulder, cobble, rubble, gravel and silt found.

Transect WR27 changed character markedly in 1983. As channel migration and bank erosion occurred the wetted channel became narrower and deeper

Table 4.4-1. Mean width, depth and velocity characteristics of White River monitoring transects (riffles only) during 1981-1983. Means were calculated from the total of all data collected along each transect during each year (complete surveys only).

Location	Year	No. of Surveys Included	Width (m)	Depth (cm)	Max Depth (cm)	Velocity (cm/s)	Maximum Velocity (cm/s)
WR03	1981	8	38.5	25.1	55.8	57.5	109.0
	1982	6	45.9	32.1	68.2	63.6	122.7
	1983	5	49.5	49.4	77.6	53.1	109.2
WR18	1981	10	40.1	31.0	59.5	69.4	141.9
	1982	8	45.6	44.9	79.8	82.0	145.1
	1983	5	47.1	41.6	79.0	88.3	161.0
WR27	1981	6	41.2	32.3	79.7	69.6	127.8
	1982	6	39.3	48.1	110.8	72.4	125.4
	1983	3	36.9	62.6	116.0	78.6*	134.5*

* WR27 value based on two surveys pre-runoff. Data is inadequate for comparison.

Table 4.4-2. Mean substrate composition of White River monitoring transects (riffles only) during 1981-1983. Means were calculated from the total of all data collected along each transect during each year (complete surveys only).

Location	Year	No. of Surveys Included	Mean Percent In Substrate Size Class						
			BO	CO	RU	GR	SA	SI	CL
WR03	1981	6	38.2	29.8	7.0	0.7	4.6	16.1	3.6
	1982	6	40.2	25.2	13.7	10.2	4.8	6.0	0.0
	1983	5	32.2	21.1	14.6	21.7	3.1	7.3	
WR18	1981	9	42.6	31.4	20.1	5.0	0.0	0.5	0.5
	1982	8	19.1	22.6	25.6	12.8	7.1	12.8	0.0
	1983	5	27.2	13.5	16.1	22.8	1.8	18.6	0.0
WR27	1981	6	9.8	54.4	13.5	8.6	3.0	3.5	0.0
	1982	6	9.2	22.3	25.3	11.4	12.7	19.0	0.0
	1983	3	3.4	8.5	11.8	24.4	33.8	22.2	0.0

(Figure 4.4-2, Table 4.4-1) and average velocity increased. These changes resulted in a change from riffle-type habitat to that of a run. Substrate composition reflected this change in character with a shift to dominance by the smaller size fractions gravel, sand and silt (Table 4.4-2). These size fractions are typical of swift, unstable habitats. This change in WR27 resulted in a loss of comparability to WR03 and WR18. WR27 was discontinued in August, 1983. Another transect downstream of Tracts Ua and Ub will be added in 1984. This will be WR21 which was surveyed originally in 1981. That location was an excellent riffle transect but was not used for long-term data collection due to limited access.

Interstitial sediment data for the three monitoring transects are shown in Figure 4.4-3. Transects WR03 and WR18 have maintained consistency through three years of data collection, being dominated by the larger size fractions. The rare exception to this has occurred twice on WR18 when ice dams slowed the current and allowed deposition of large quantities of fine sediments. The interstitial sediment composition on WR27 began shifting to dominance by the smaller sizes in 1982 reflecting a gradual change in character of this transect, reinforcing the changes observed in substrate characteristics and channel morphology from stream survey data.

Total suspended solids reached higher levels than in 1981 and 1982 (Figures 4.4-4 and 4.4-5). The maximum levels occurred in early June (8000 mg/l) and late August (11567 mg/l). Similar temporal patterns were observed on each transect although there were differences in magnitude. These differences were due to samples being taken at each transect on different days, probably reflecting differences in discharge or storm inputs. During

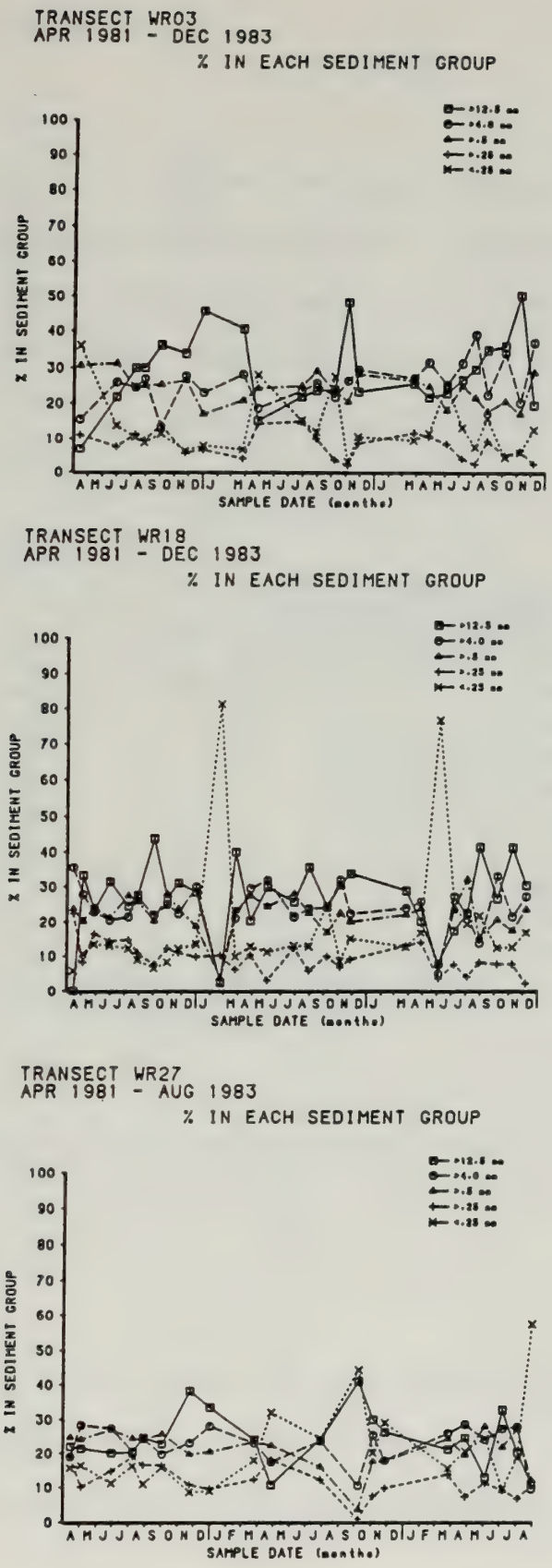

Figure 4.4-3. Interstitial sediment size fractions for White River Transects WR03, WR18 and WR27 from April, 1981 to December, 1983.

1984, samples will be scheduled on the same day at all locations. Light penetration data for 1983, as in 1982, reflected increased turbidity due to higher suspended solids loads (Figures 4.4-6 and 4.4-7). A pattern of increased light penetration during the winter months, November to January, has been documented during both 1982 and 1983.

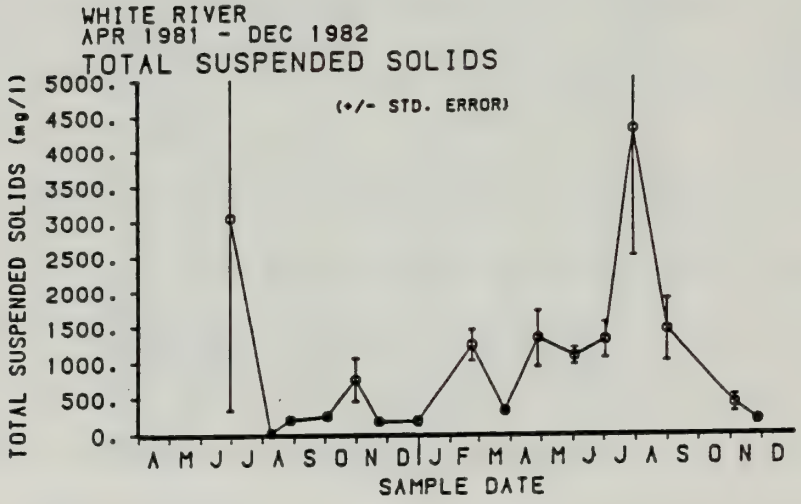

Figure 4.4-4. Total suspended solids data for White River Transect WR18 from April, 1981 to December, 1982.

Water temperature in the White River near Asphalt Wash appeared to follow the same pattern in 1983 as in 1982 although data for the summer period, June through September, was not available (Figure 4.4-8).

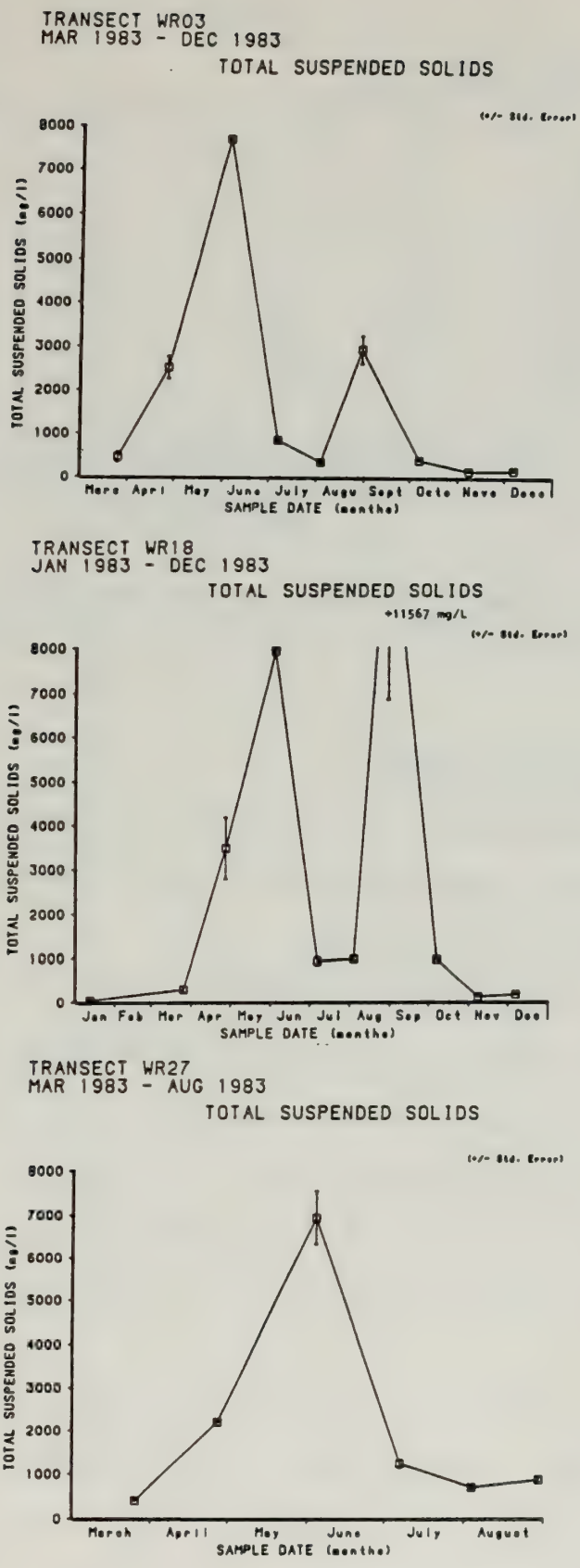

Figure 4.4-5. Total suspended solids data for White River Transects WR03, WR18 and WR27 during 1983.

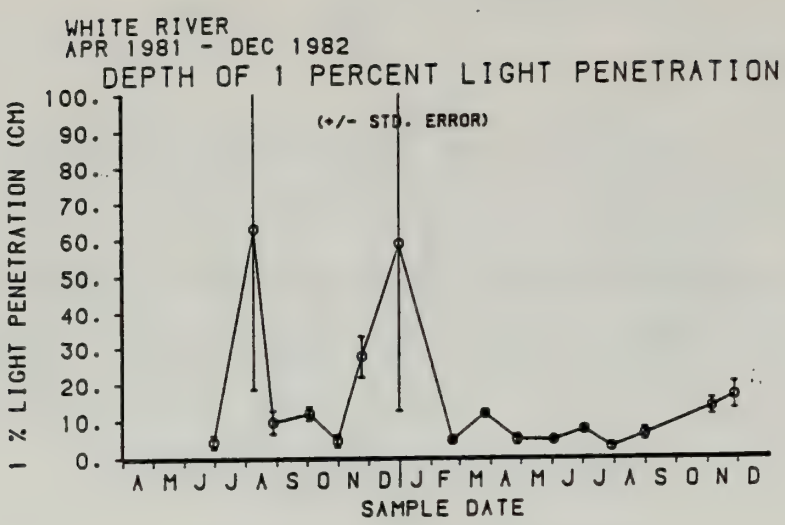

Figure 4.4-6. Depth to 1% incident light penetration for White River Transect WR18 for each sample period in 1981 and 1982.

4.4.2 The Chemical Environment

During 1983 data continued to be collected on macrochemistries important to the biotic community. These included pH, conductivity and major forms of the nutrients, phosphorus and nitrogen.

Conductivity followed the same pattern observed in 1982 (Figures 4.4-9 and 4.4-10). Values reached a peak of around 900 umhos/cm during lower basin runoff in March of both years. During upper basin runoff, in June, as dilution took place conductivity declined to low values of approximately 300 umhos/cm. Following upper basin runoff, in summer and fall, values again increased to a level of around 700 umhos/cm. pH remained constant at values near eight.

The patterns of nutrient concentrations measured at Transect WR18 during 1981 and 1982 are shown in Figure 4.4-11. Total phosphorus and orthophosphate consistently followed a pattern of increased levels during high flows. Total inorganic nitrogen (TIN) has followed a similar pattern but has been more variable.

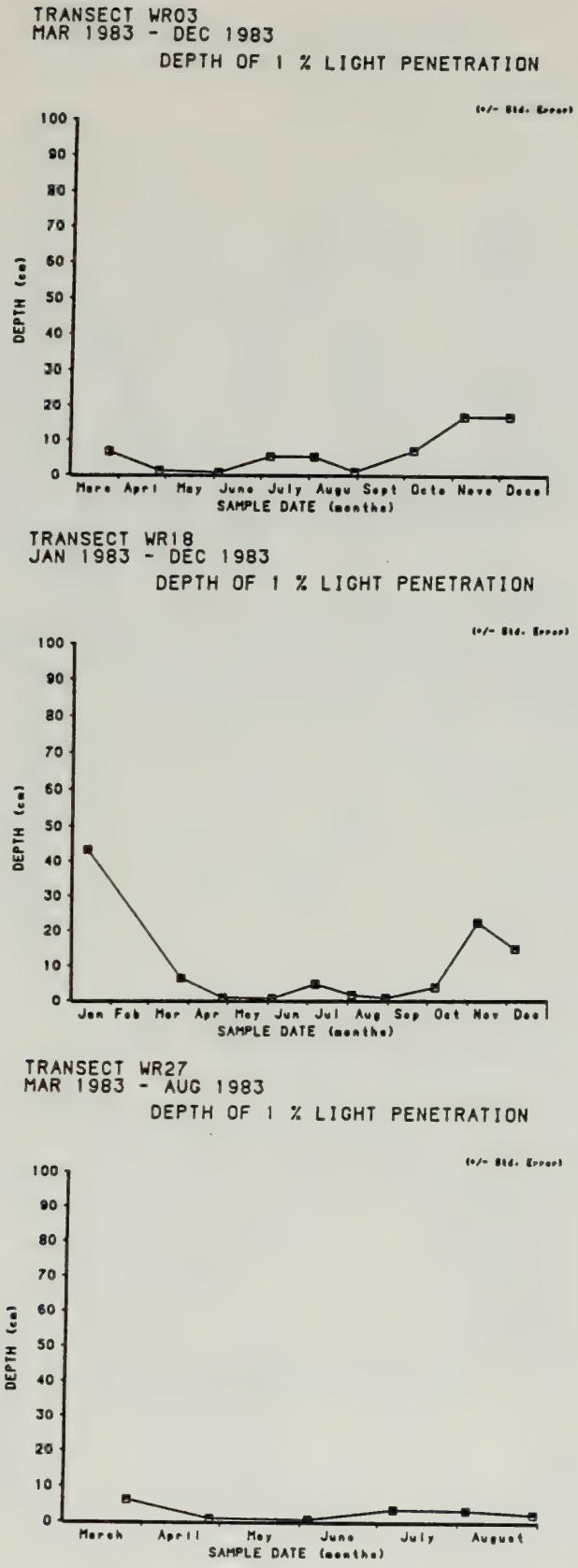

Figure 4.4-7. Depth to 1% incident light penetration for White River Transects WR03, WR18 and WR27 during 1983.

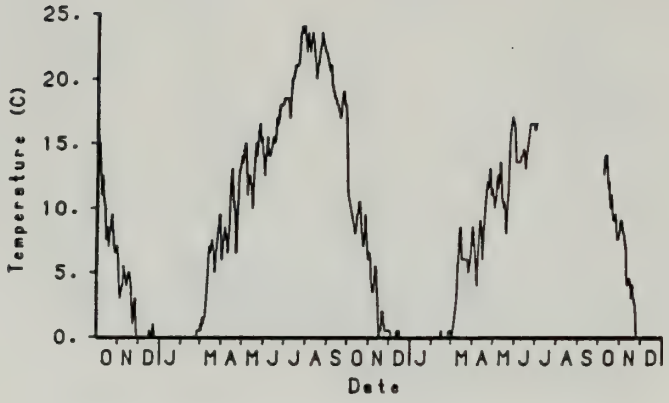

Figure 4.4-8. Water temperatures in the White River near Asphalt Wash at Station 6700 between October, 1981 and December, 1983. Data from VTN.

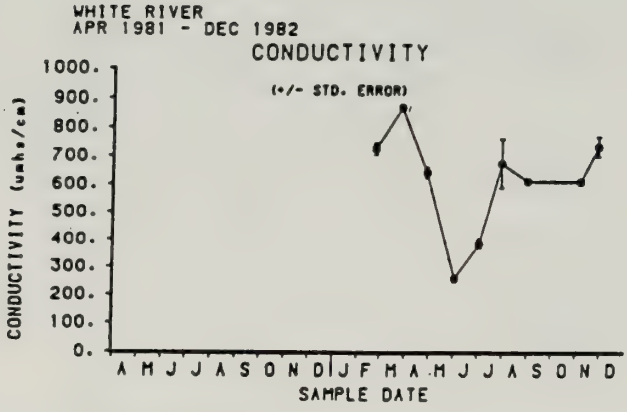

Figure 4.4-9. Conductivity in the White River at Transect WR18 during 1982 sample sessions.

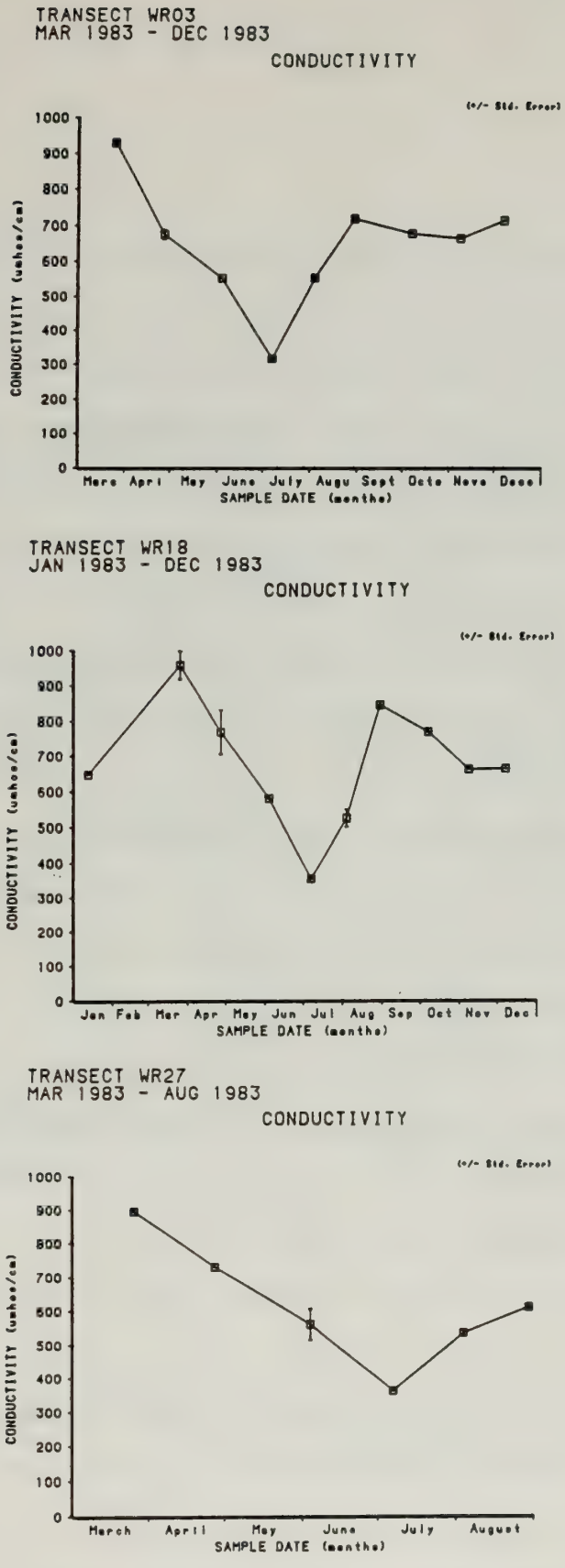

Figure 4.4-10. Conductivity data for White River Transects WR03, WR18 and WR27 during 1983.

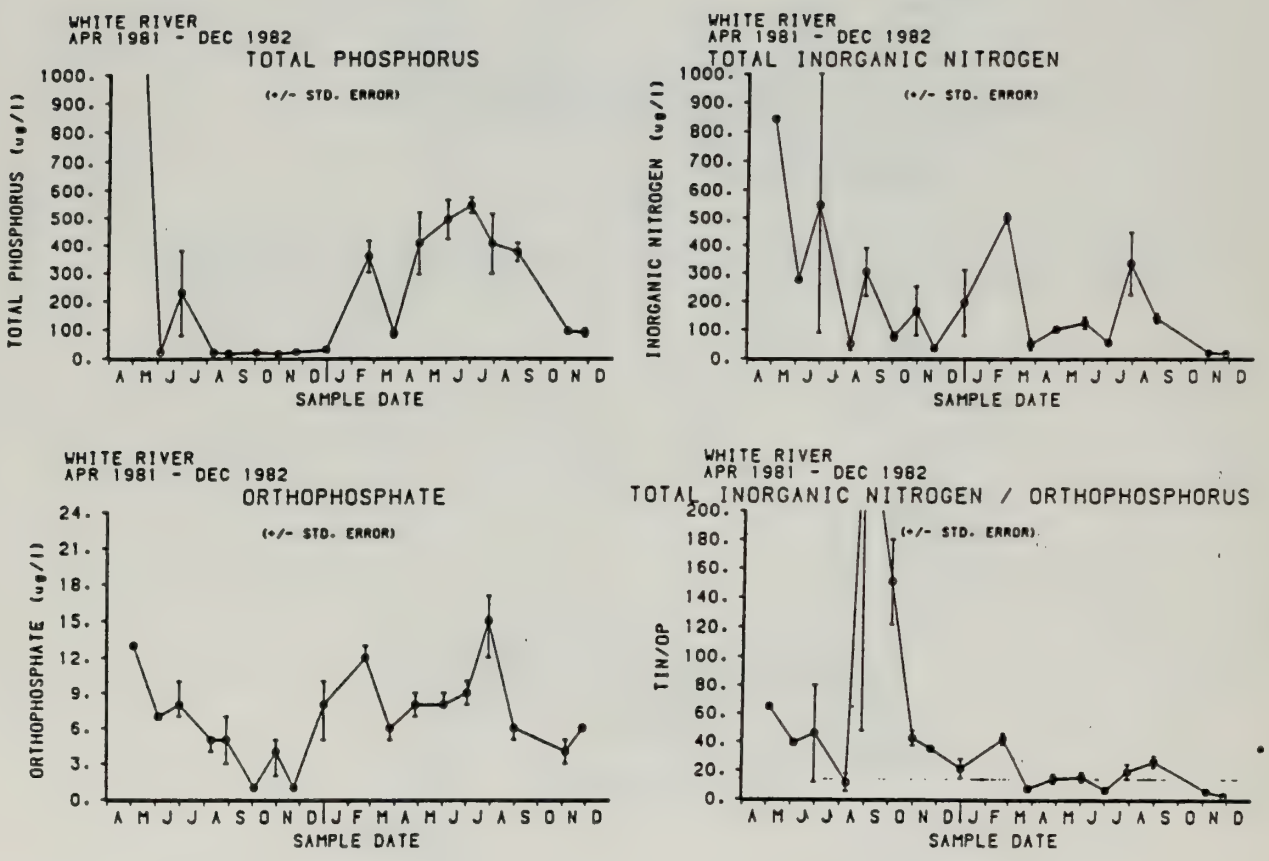

Figure 4.4-11. Total phosphorus, reactive phosphorus (orthophosphate) total inorganic nitrogen (NH_3 + NO_3 +NO_2) in the White River at Transect WR18 during 1981 and 1982.

During 1983, TIN followed similar patterns with discharge as in previous years except concentrations were generally higher than 1981 and 1982 (Figure 4.4-12). TIN values reached 700 ug/l during June at each transect as compared to 500 in June, 1982 and 550 in June, 1981. Values for the summer and fall were generally higher as well. As in previous years nitrate (NO_3) was the dominant form with ammonia (NH_3) and nitrite (NO_2) occurring at much lower levels (Figure 4.4-13).

Total phosphorus levels were higher than in 1981 or 1982 (Figures 4.4-11 and 4.4-14). This reflected particulate forms carried into the White River by overland flow during lower and upper basin runoff in this higher than normal flow year. Total phosphorus levels peaked during upper basin runoff in June between 4000 and 6000 ug/l. August levels at WR18 and WR03 were elevated, due to input from storm events (flash floods) in Southam Canyon and Evacuation Creek. Total suspended solids and inorganic nitrogen levels reflect this pattern as well (Figures 4.4-5 and 4.4-12). Transect WR27 did not reflect these patterns as sampling occurred there prior to the storm event. Orthophosphate levels reflected a similar pattern (Figure 4.4-15).

The ratio of total inorganic nitrogen to orthophosphate (TIN/OP) is used by limnologists to indicate when either of the major nutrients is in short supply relative to the other. When the ratio exceeds 15:1 the system is presumed to be phosphorus limited and when the ratio is less than 15:1 nitrogen limitation is presumed to occur. During 1983 the (TIN/OP) ratio was always greater than 15:1 (Figure 4.4-16) indicating phosphorus limitation. Due to the high suspended solids load and low light penetration it is felt

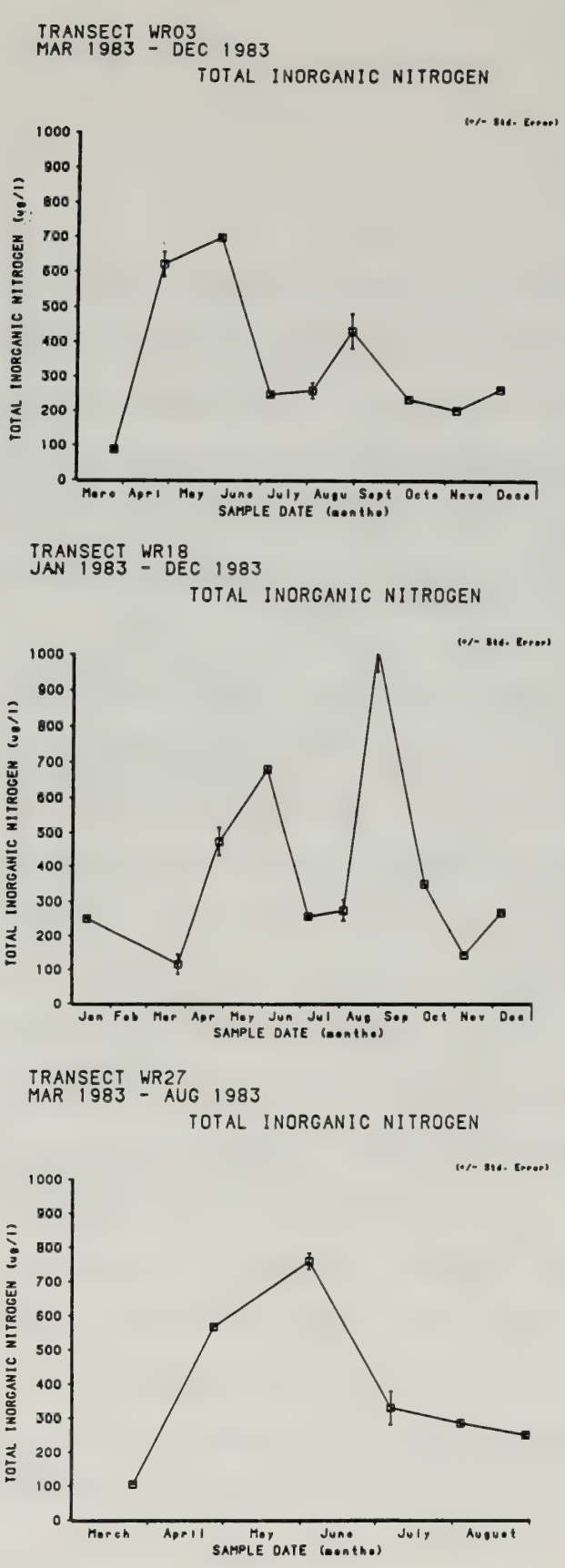

Figure 4.4-12. Concentration of total inorganic nitrogen (NH_3 + NO_3 + NO_2) for White River Transects WR03, WR18 and WR27 during 1983.

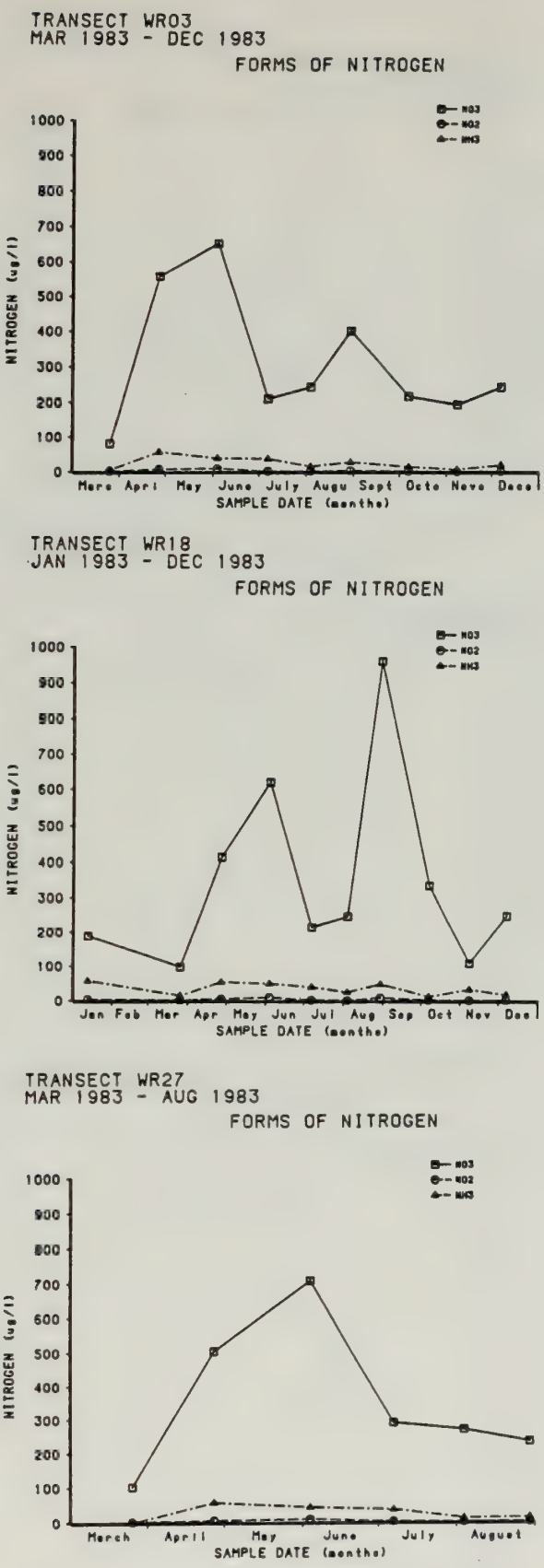

Figure 4.4-13. Concentration of the forms of inorganic nitrogen (NH_3 + NO_3 + NO_2) compromising total inorganic nitrogen for White River Transects WR03, WR18 and WR27 during 1983.

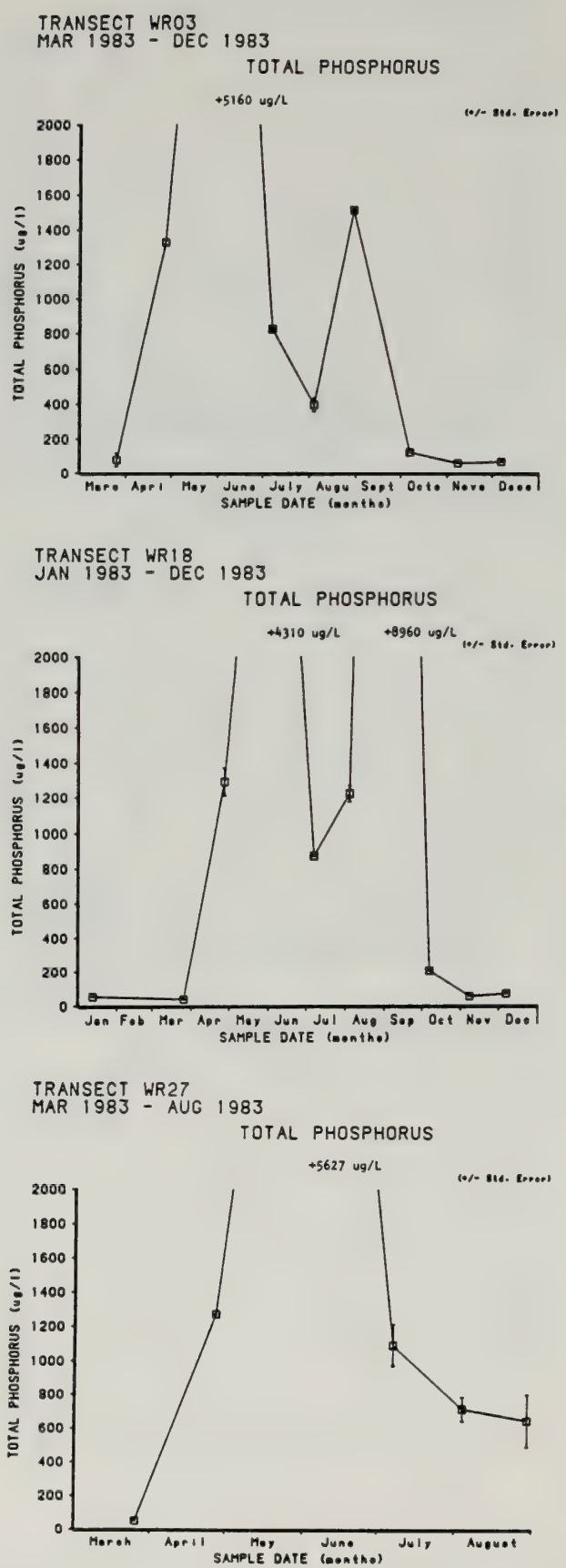

Figure 4.4-14. Concentration of total phosphorus for White River Transects WR03, WR18 and WR27 during 1983.

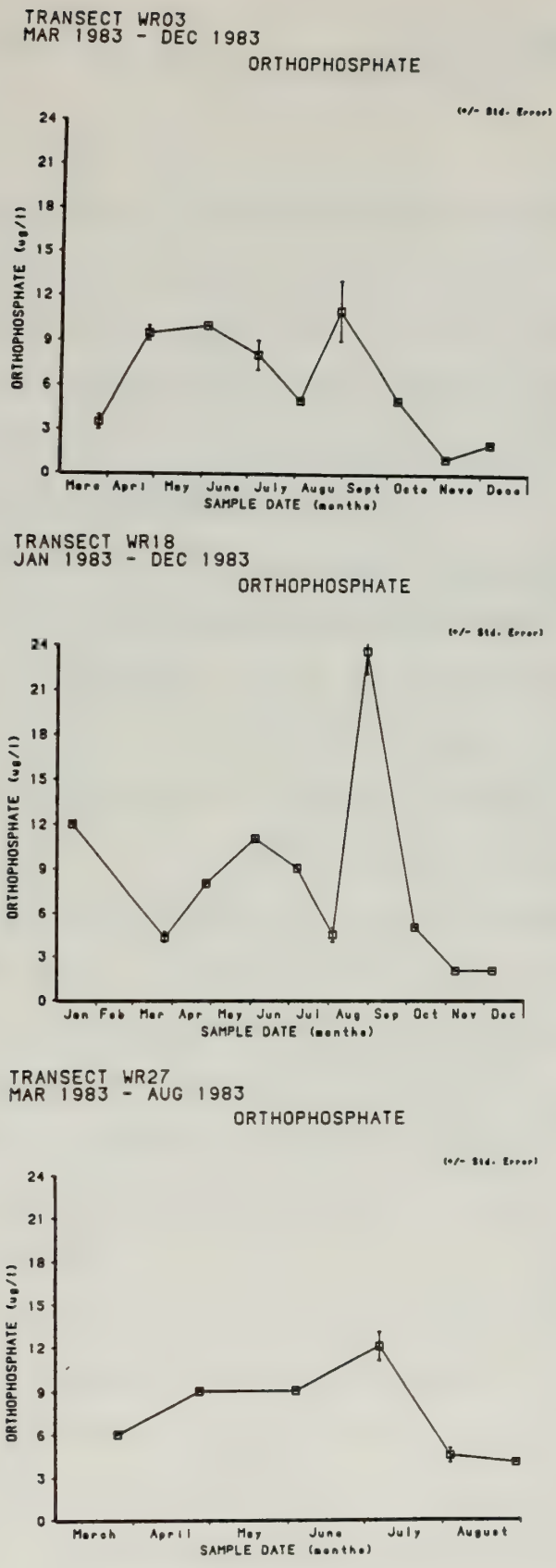

Figure 4.4-15. Concentration of orthophosphate for White River Transects WR03, WR18 and WR27 during 1983.

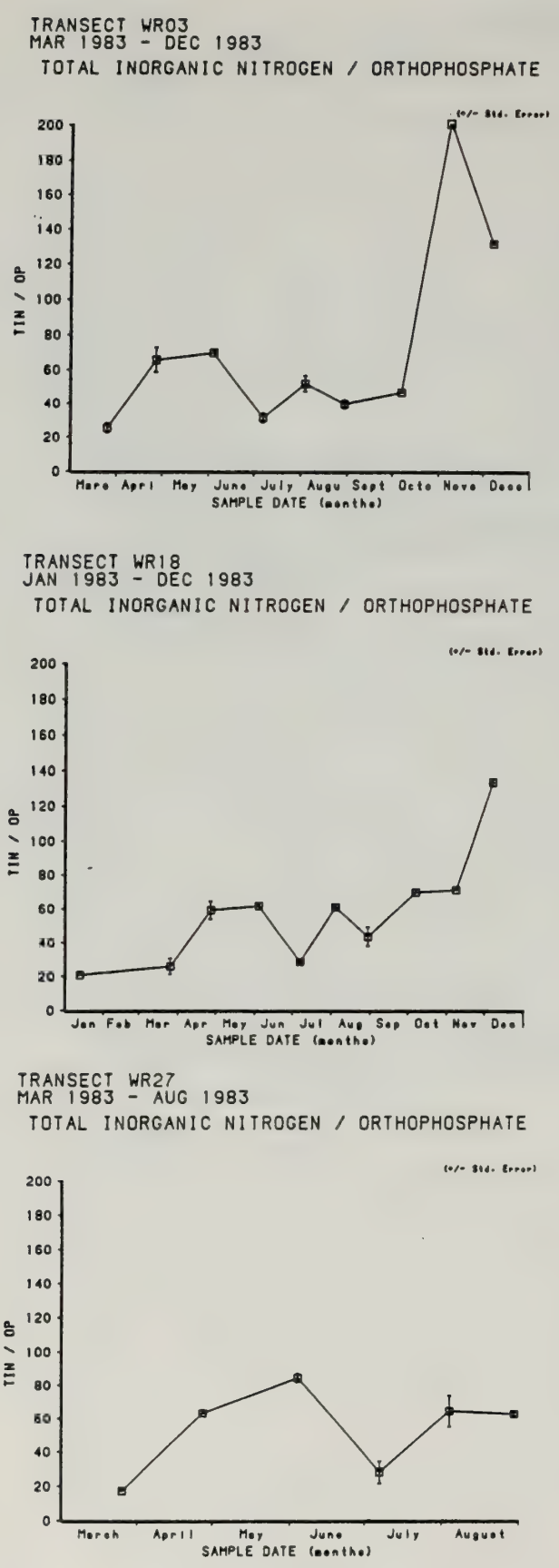

Figure 4.4-16. Total inorganic nitrogen to orthophosphate ratio for White River Transects WR03, WR18 and WR27 during 1983.

that, during most of the year, insufficient light reaches the substrate to promote maximum algae growth with the nutrients present. Inspection of Figure 4.4-16 reveals TIN/OP ratios greater than 15:1 (presumably phosphorus limited) for July and December, 1981 when light penetration was greatest (>60 cm). Algal standing crops during those periods were high.

4.4.3 The Organic Environment

Organic matter within streams is an important source of energy for many stream organisms. Sources of organic matter are either external (terrestrial plants) and enter the river with surface flow or are internal and are produced within the river (aquatic plants and algae). This organic matter resides in two dominant compartments defined by Cummins (1974) as CPOM and FPOM. CPOM or coarse particulate organic matter taken here as greater than 1 mm in size can be processed by physical abrasion or animals into FPOM, fine particulate organic matter, less than 1 mm in size. In the aquatic biology monitoring program three parameters are measured to characterize the organic environment. These are organic matter drifting (DRIFT), benthic organic matter associated with invertebrate samples (CPOM) and organic matter contained in the interstitial sediment (FPOM) available to burrowing invertebrates and microbes.

Drifting organic matter through 1983 has been measured somewhat crudely as total coarse particulate matter drifting per hour. This constitutes an approximation to the amount of drift only in that samples were taken for similar time periods and in areas of similar velocity. Based upon characteristics of the ERI drift nets determined during 1983, future samples will be standardized to discharge (gm/m^3).

Due to problems in data reduction, data for drifting organics will not be presented in this report but will follow in a subsequent quarterly report.

The amount of benthic organic matter (CPOM) associated with macroinvertebrate samples is shown in Figure 4.4-17. The general pattern of CPOM consists of high values as lower basin runoff occurs, gradually declining through summer and fall. Exceptions occur due to periodic inputs from storms or during periods of warm water with low turbidity such as June through October, 1981. The abnormally high data points during early June, 1983 at WR18 and WR27 resulted from sampling near shore in a shallow area which had trapped large amounts of floating debris during this high flow period. Barring these two abnormal points the levels of benthic organics appeared similar between 1982 and 1983.

Interstitial sediment organic matter (FPOM) has maintained a level near 1% of the sediment size fraction less than 0.25 mm at all transects during the period April, 1981 until December, 1983 (Figure 4.4-18). Periodic increases occur in response to runoff events, either lower and upper basin or storm events. This pattern has been most evident on WR18.

4.4.4 Primary Producers

The primary producers or algae in the White River constitute a second important energy source for the other trophic levels residing there. The algal community in the White River is quite diverse and appears to be regulated by physical factors.

The pattern of chlorophyll *a* as a measure of periphyton biomass in the White River is presented in Figure 4.4-19. It was suggested in WRSOC (1983) that algal standing crops were driven by available light in the White River.

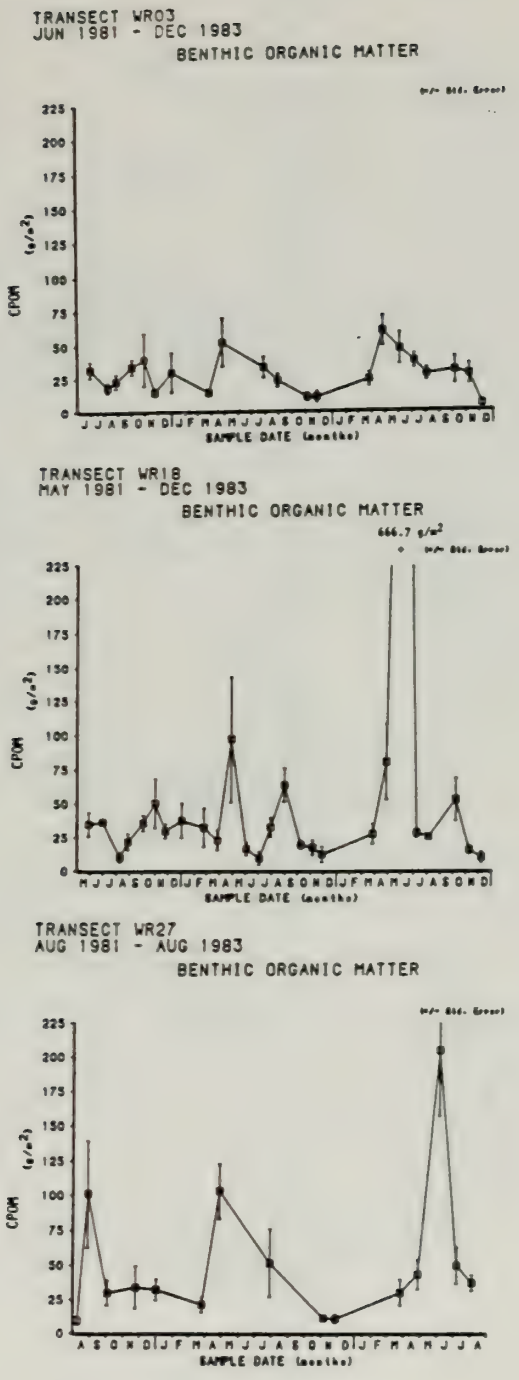

Figure 4.4-17. Benthic organic matter (CPOM) contained in macroinvertebrate samples for White River Transects WR03, WR18 and WR27 from May, 1981 to December, 1983. Each data point is the mean of five samples taken along the transect.

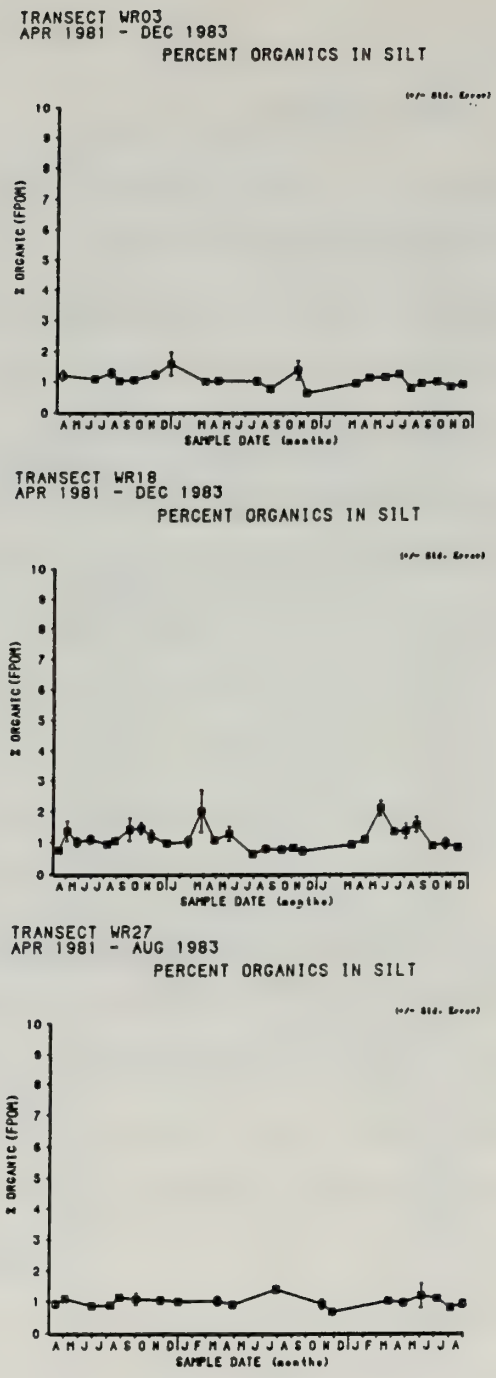

Figure 4.4-18. Sediment organic matter (FPOM) as a percent of the (-0.25mm) sediment size fraction for White River Transects WR03, WR18 and WR27 from April, 1981 to December, 1983.

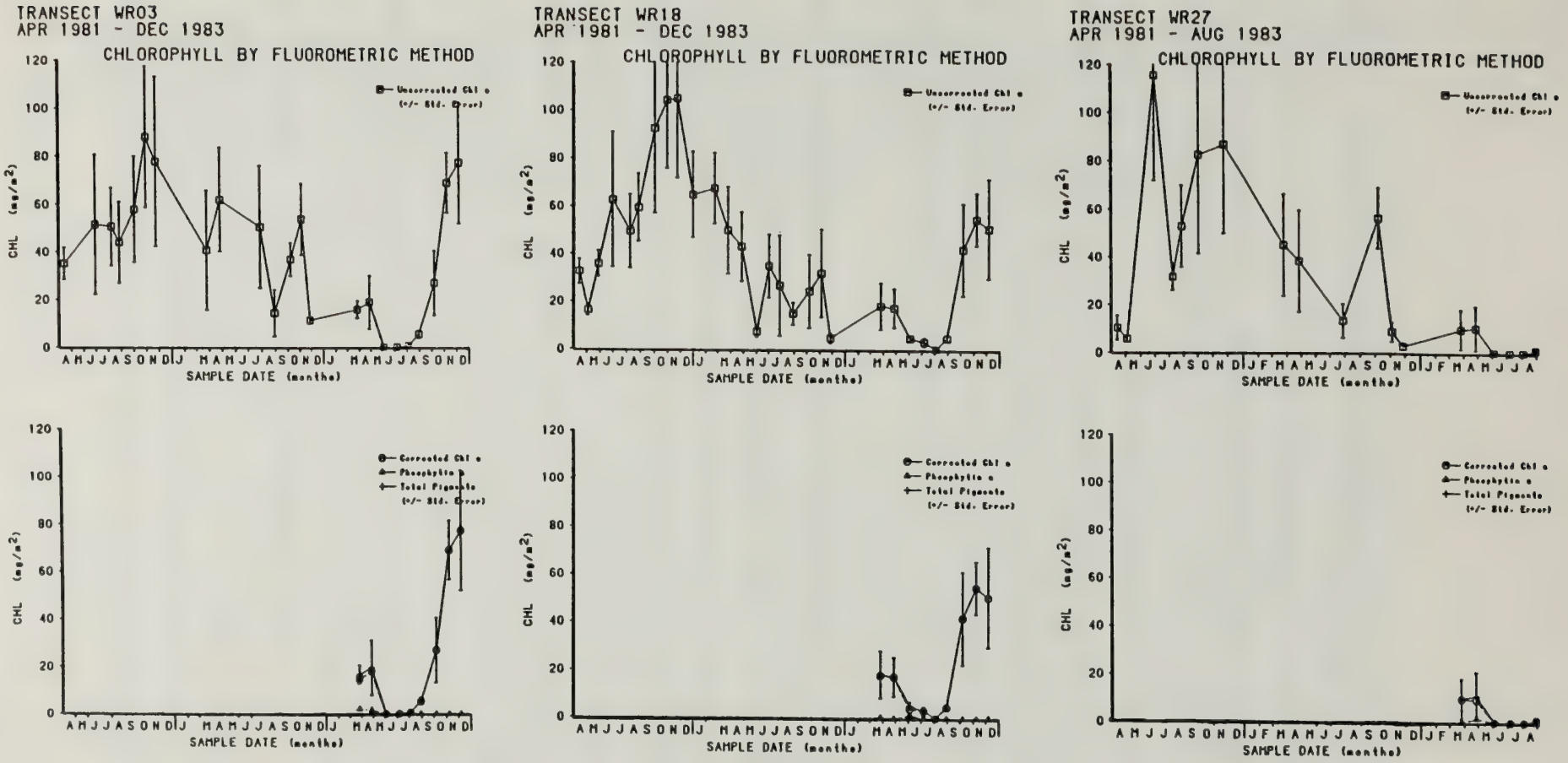

Figure 4.4-19. Periphyton biomass as chlorophyll a for White River Transects WR03, WR18 and WR27 from April, 1981 unitl December, 1983.

As light increased, algal standing crops were observed to increase except when scouring by silt occurred during high flows or ice occurred during the winter months. It has been observed that in November when ice is beginning to form in the river that the freshly formed ice crystals exert a large scouring force on the algal community.

The periphyton biomass measured on Transects WR03 and WR18 reflected these patterns well with increasing algal crops occurring parallel with increasing light levels in the river. During periods of scouring with or without high available light algal standing crops slowed or declined in standing crop.

Data from Transect WR27 may illustrate another physical dependence of algal production. That is a dependence upon stable substrate. This is difficult to evaluate at this point because the lack of large substrates at WR27 during 1983 was confounded by increased water depth. It is evident from observations over three years in the White River that substrate that is mobile typically has little or no periphyton present. Comparisons of periphyton biomass as chlorophyll a between transects and time are made in a later section of this report.

Taxonomically, the White River in the study section is rich in periphyton diatom species, with other phyla being represented to a lesser degree (Table 4.4-3). A total of approximately 86 species of algae have been documented by the White River Shale Project aquatic biology sampling since 1974. Sixty-four of these taxa were diatoms. The greatest number of taxa were documented during the 1974-1975 baseline study (51) while 1982 was the year with fewest taxa (27).

Table 4.4-3. Presence of taxa of periphytic algae present on the White River near Tracts Ua and Ub.

Taxa	PRESENCE OR ABSENCE BASELINE 1974-1975	ERI 1981	ERI 1982	ERI 1983
Sub-Phylum Bacillariophyceae				
Achnanthes lanceolata	P			
var. dubia				P
Achnanthes linearis	P	P		P
Amphiprora palludosa	P			
Amphiprora ornata	P			
Amphora coffeae formis	P			
Amphora ovalis	P			
Amphora pusilla		P	P	P
Cocconeis placentula		P	P	P
var. lineata	P			
Cyclotella meneghiniana	P			
Cyclotella sp.			P	
Cylindrotheca gracilis	P			
Cymbella affinis		P	P	P
Cymbella mulleri	P			
Cymbella sinuata		P	P	P
Cymbella sp.	P	P		
Diatoma hiemale	P			
Diatoma vulgare	P	P	P	P
Epithemia sorex	P	P	P	P
Fragillaria capucina		P		P
Fragillaria vaucheriae		P	P	P
Fragillaria sp.	P			
Gomphoneis herculeana		P	P	P
Gomphonema intracatum		P	P	P
Gomphonema olivaceum	P	P	P	P
var. calcarea		P	P	P
Gomphonema parvulum		P		P
Gyrosigma spencerii		P		P
Gyrosigma sp.	P			
Mastigloia sp.	P			
Navicula cryptocephala	P			P
var. minuta		P	P	P
var. veneta		P	P	P
Navicula holop		P		P
Navicula minuscula		P	P	P
Navicula radiosa	P	P	P	P
Navicula salinarum				
var. intermedia		P	P	P
Navicula tripunctata	P	P	P	P
Navicula viridula		P	P	P
Navicula zanoni	P			
Navicula sp.	P			
Nitzschia aris		P		P
Nitzschia apiculata				P
Nitzschia denticula				P
Nitzschia dissipata		P	P	P
Nitzschia fonticola		P	P	P
Nitzschia palea		P	P	P
Nitzschia tryblionella	P		P	P
Nitzschia sp.1		P	P	P
Nitzschia sp.2		P		P
Nitzschia sp.3		P		P
Nitzschia sp.	P			
Pinnularia sp.	P			
Pleurosigma sp.	P			
Rhoicosphenia curvata		P	P	P
Rhopalodia gibba	P	P		
Rhopalodia gibberula	P			
Surirella ovalis	P			
Surirella ovata	P			P
Synedra acus	P			
Synedra pulchella				P
Synedra ulna	P			P
Syndra sp.	P			
Total Bacillariophyceae Taxa	34	33	25	39

Table 4.4-3. (Continued).

Taxa	PRESENCE OR ABSENCE BASELINE 1974-1975	ERI 1981	ERI 1982	ERI 1983
Phylum - Chlorophyta				
Cladophora glomerata	P			
Cladophora sp.	P	P	P	P
Fritschiella sp.		P		
Mougeotia sp.	P			
Oedogonium sp.	P	P		
Pediastrum sp.				P
Scenedesmus sp.		P		
Spirogyra sp.	P			
Ulothrix sp.	P	P		
Zygnema sp.	P	P		
Total Chlorophyta Taxa	7	6	1	2
Phylum - Chrysophyta				
Vaucheria sp.	P			
Total Chrysophyta Taxa	1	0	0	0
Phylum - Cyanophyta				
Arabena sp.	P			
Aphanothece sp.	P			
Chroococcus sp.	P	P	P	
Lyngbya sp.	P			
Nostoc sp.		P		
Oscillatoria sp.	P	P		
Phormidium sp.	P			
Rivularia sp.	P	P		
Spirulina sp.	P			
Synecocystis sp.	P			
Unidentified				P
Total Cyanophyta Taxa	9	4	1	1
Total All Phyla	51	43	27	42

Rushforth et al. (1981) presented an analysis of diatom communities in the Uintah Basin of Utah in which they attempted to correlate diatom species with water quality parameters, particularly heavy metals. Many of the species of diatom they associated with metal tolerance or intolerance occur in the White River near Tracts Ua and Ub. A detailed analysis of the periphyton data collected on the White River since 1981 will be performed during 1984. Results of these analyses and comparisons with the literature will be presented in a separate report to WRSOC.

4.4.5 Consumers

The consumer community measured in the White River aquatic biology monitoring program consists of the stream invertebrates. Fish have not been regularly monitored because of the difficulty and expense of collecting sufficient data for comparison and the mobility of the organism (ERI 1984). This subsection discusses the dynamics of overall macroinvertebrate community parameters during 1981-1983 and describes the taxonomic composition of the community. A comparison of taxa observed during the 1981-1983 program is made with those found during the 1974-1975 baseline period.

A later section will examine macroinvertebrate sampling using introduced substrates and will compare data using substrates to normal sampling methods. Additional analyses will address the nature of variability of macroinvertebrate parameters over time, between transects and between locations within a transect.

The number of taxa of invertebrates varies widely over short time periods (Figure 4.4-20). This reflects losses due to emergence and drift as well as gains from upstream drift and reproduction. There is no distinct

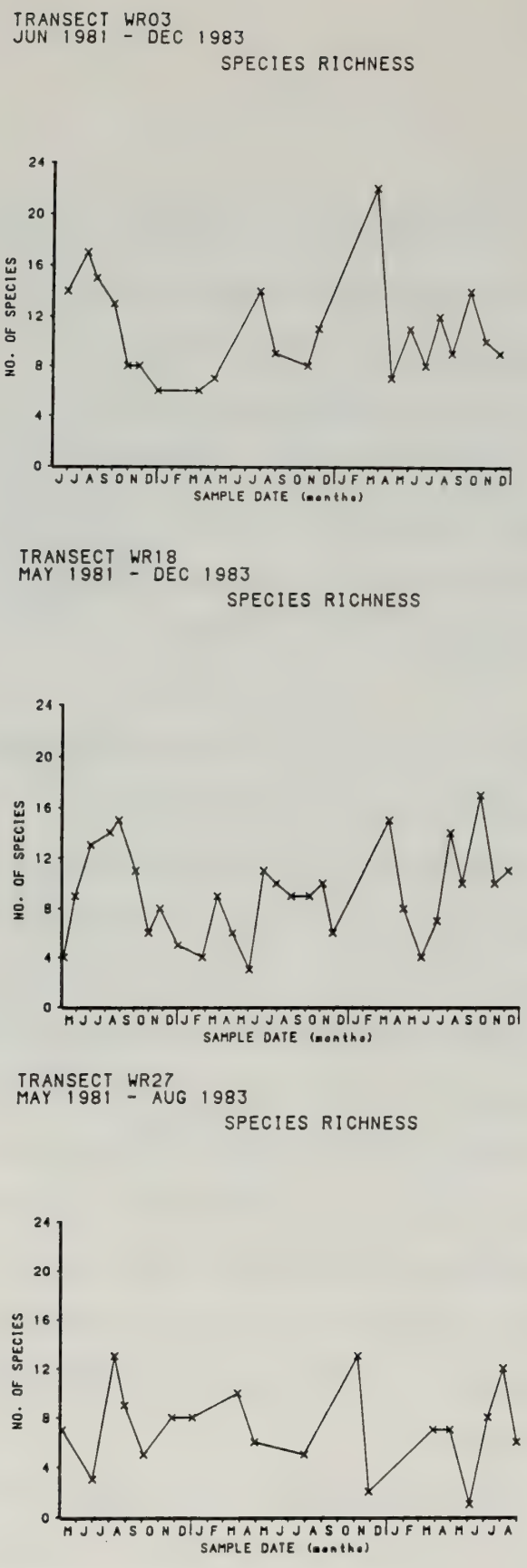

Figure 4.4-20. Taxonomic richness of benthic macroinvertebrate community for White River Transects WR03, WR18 and WR27 from April, 1981 to December, 1983.

pattern to species richness over time although richness appears to increase during periods of increased light penetration, particularly following upper basin runoff as temperatures are also rising. WR03 and WR18 exhibited this pattern and attained maxima of 16 or more taxa. WR27 rarely exceeded 12 taxa and generally contained fewer taxa than the upstream transects. The lower amount of large substrate at WR27 combined with lower substrate stability apparently limits the richness of the community at this location.

Numbers and biomass of benthic invertebrates occurring on riffle transects continued to follow a pattern of increase during periods of high light penetration and lower flows (Figures 4.4-21 and 4.4-22). Transects WR03 and WR18 continued to be most productive with WR27 least productive. Apparently the lack of suitable substrate limits the macroinvertebrate community on WR27. Peak flows generally depress numbers and biomass, probably through increased downstream drift.

The White River maintains a diverse community of aquatic invertebrates. During the baseline period in 1974-1976, 30 different taxa were documented (VTN 1977). Forty-two taxa have been found so far in the current aquatic biology monitoring program (Table 4.4-4). Though some differences exist between the two time periods with some invertebrates found during one period not being found during the other, generally the community composition appears similar. Classification of the invertebrates into functional groups based on food source (Merritt and Cummins 1978) and guilds based upon mode of feeding (Hawkins et al. 1982) is presented in Table 4.4-5.

Functionally, the invertebrate community is dominated by collector-gatherers and filter-feeding invertebrates which are omnivorous

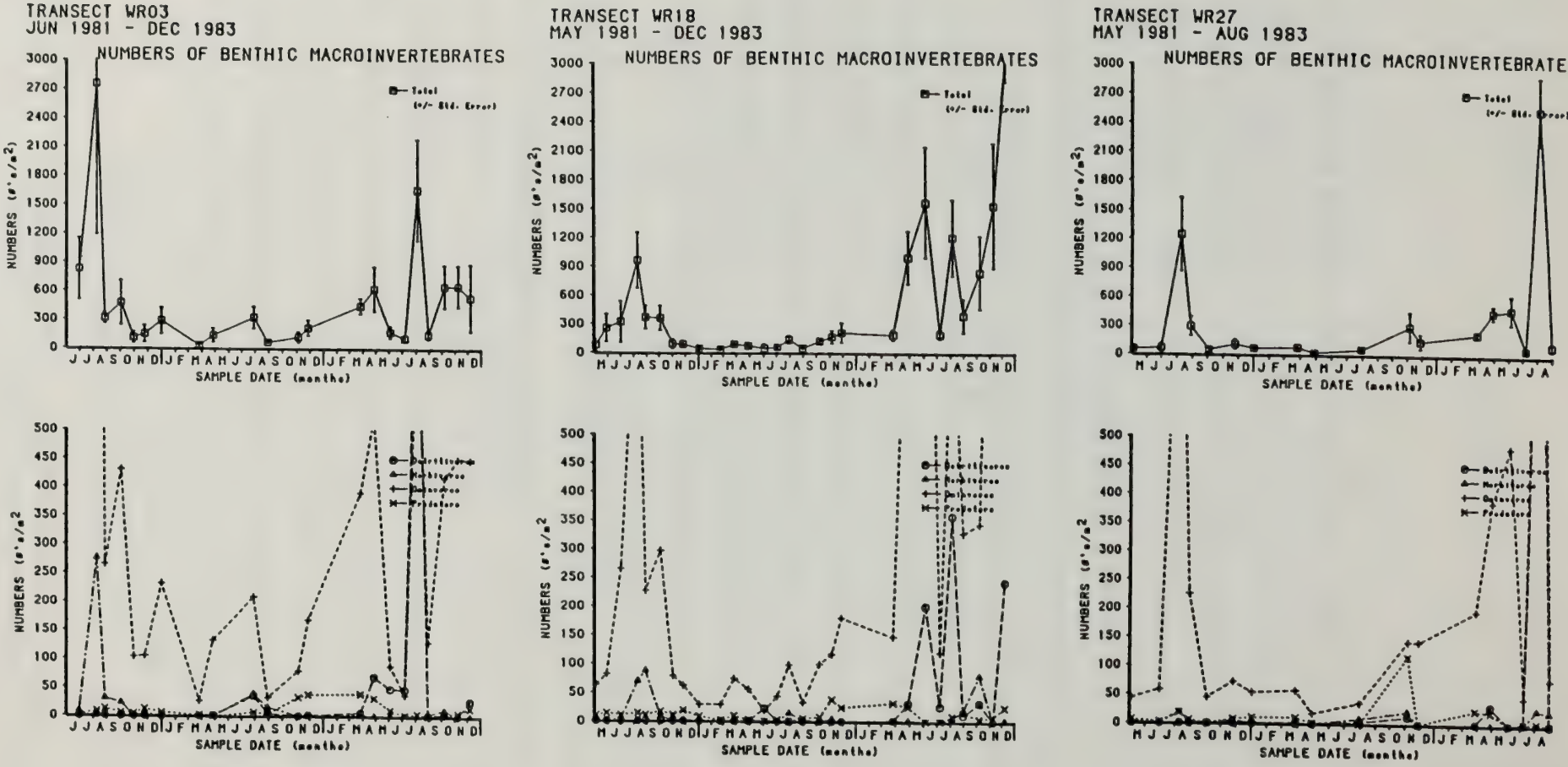

Figure 4.4-21. Numbers of benthic macroinvertebrates by functional group and totals for White River Transects WR03, WR18 and WR27 from April, 1981 to December, 1983.

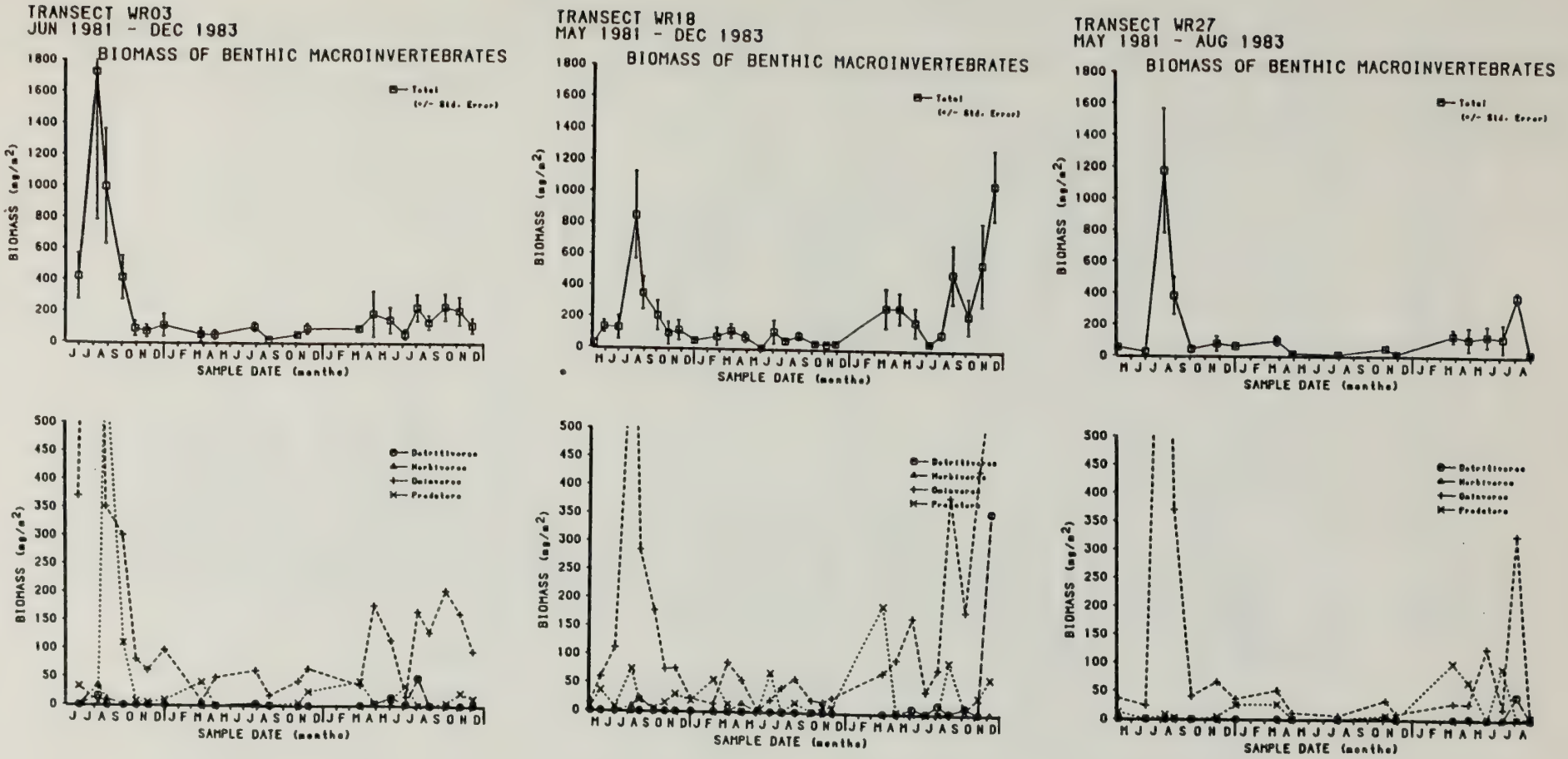

Figure 4.4-22. Calculated biomass of benthic macroinvertebrates by functional group and totals for White River Transects WR03, WR18 and WR27 from April, 1981 to December, 1983.

Table 4.4-4. Taxa of aquatic invertebrates documented by the WRSOC aquatic monitoring program in the White River near Tracts Ua and Ub.

Taxa	BASELINE 1974-1976	ERI 1981-1983
NON-INSECTS		
Gastropoda		P
Hydracarina		P
Nematoda	P	P
Oligochaeta		P
Limnodrilus claparedianus	P	
Limnodrilus eudekemianus	P	
INSECTS (Class Insecta)		
Collembola		
Isotomurus sp.		P
Coleoptera		
Elmidae		P
Zaitzevia sp.	P	
Diptera		
Ceratopogonidae	P	
Chironomidae	P	P
Chironomus sp.	P	
Orthocladius sp.	P	
Crictopus sp.	P	
Empididae		
Hemerodromia		P
Ephydridae	P	
Heleidae		
Palpomyia sp.		P
Rhagionidae		
Atherix sp.		P
Simuliidae	P	P
Stratiomyidae		
Stratiomys sp.		P
Syrphidae	P	P
Tabanidae		P
Tipulidae		
Hexatoma sp.	P	P
Tipula sp.		P
Ephemeroptera		
Baetis sp.		P
Baetis sp 1.	P	
Baetis sp 2.	P	
Brachycercus prudens	P	
Choroterpes albiannulata	P	
Cinygmula sp.		P
Dactylobaetis sp.		P
Dactylobaetis cepheus	P	
Ephemerella sp.		P
Ephemerella inermis	P	
Ephoron album	P	
Heptagenia	P	P
Heptagenia elegantula		
Isonychia sp.		P
Lachlania sp.		P
Lachlanis saskatchewanensis	P	
Leptohyphes sp.	P	P
Paraleptophlebia sp.	P	P
Pseudocloeon turbidum	P	
Rhithrogena sp.		P
Rhithrogena undulata	P	
Traverella sp.		P
Traverella albertana	P	
Trichorythodes sp.		P
Trichorythodes edmundsi	P	
Trichorythodes minutus	P	

Table 4.4-4. (Continued).

Taxa	BASELINE 1974-1976	ERI 1981-1983
Hemiptera		
Notonectidae		P
Rhagovelia		P
Rhagovelia distincta	P	
Lepidoptera		
Paragyractis sp.		P
Odonata		
Hetaerina sp.	P	
Octogomphus sp.		P
Ophiogomphus sp.		P
Ophiogomphus severus	P	
Plecoptera		
Acroneuria abnormis	P	
Isogenoides sp.		P
Isogenoides frontalis colubrinus	P	
Isoperla longiseta	P	
Kathroperla sp.		P
Pteronarcidae		P
Taenionema sp.		P
Trichoptera		
Brachycentrus sp.	P	P
Hydropsyche sp.		P
Hydropsyche sp. A	P	
Hydropsyche sp. B	P	
Hydroptila sp.		P
Lepidostomatidae		P
Leptocella sp.	P	
Lepidoptera		
Noctuidae		P
Total Invertebrate Taxa	39	42

Table 4.4-5. Classification of aquatic invertebrates found in the White River during 1981- 1983 into functional groups and guilds.

Taxa	Functional Group (Merritt and Cummins 1978)	Guild (Hawkins et. al. 1982)
Oligochaeta	Omnivore	Collector/Gatherer
Hydracarina	Predator	Predator
Collembola		
isotomurus	Omnivore	Collector/Gatherer
Coleoptera		
Elmidae	Omnivore	Collector/Gatherer(Scrapers)
Diptera		
Chironomidae	Omnivore	Collector/Gatherer (Predators)*
Empidae hemerodromia	Omnivore	Collector/Gatherer (Predators)
Helidae palpomyia	Omnivore	Collector/Gatherer (Predators)
Rhagionidae atherix	Predator	Predator
Simulidae	Detritivore	Filterer
Stratiomydae stratiomys	Onmivore	Collector/Gatherer
Syrphidae		
Tabanidae	Predator	Predator
Tipulidae hexatoma	Predator	Predator
Tipulidae tipula	Omnivore	
Ephemeroptera		
Baetidae baetis	Omnivore	Collector/Gatherer
Baetidae dactylobaetis	Omnivore	Collector/Gatherer
Ephemerellidae ephemerella	Omnivore	Collector/Gatherer
Heptagenidae cinygmula	Omnivore	Collector/Scraper*
Heptagenidae heptagenia	Omnivore	Collector/Scraper*
Heptagenidae rhithrogenia	Omnivore	Collector/Scraper*
Leptophlebidae paraleptophlebia	Omnivore	Collector/Gatherer*
Lepttophlebidae traverella	Omnivore	Filterer
Oligoneuridae lachlania	Omnivore	Filterer
Siphlonuridae isonychia	Omnivore	Filterer (Predators)
Tricorythidae tricorythodes	Omnivore	Collector/Gatherer
Tricorythidae lepthohyphes	Omnivore	Collector/Gatherer
Hemiptera		
Notonectidae	Carnivore	Predator
Veliidae rhagovelia	Predator	Predator
Lepidoptera		
Pyralidae paragyractis	Herbivore	Scraper
Nematoda		
Odonata		
Gomphidae octogomphus	Predator	Predator
Gomphidae ophiogomphus	Predator	Predator
Gomphidae libelluidae	Predator	Predator
Plecoptera		
Chlorperlidae		
Chlorperlidae kathroperla	Omnivore	Collector/Gatherer
Perlodidae isogenoides	Predator	Predator
Pteronarcidae	Omnivore	Shredders
Taeniopterygidae taelonema	Herbivore	Scraper
Trichoptera		
Brachycentridae brachycentrus	Omnivore	Filterer
Hydroptilidae hydroptila	Herbivore	Scraper
Hydropsychidae hydropsyche	Omnivore	Filterer
Lepidostomatidae		
Lepidoptera		
Noctuidae	Herbivore	Shredder
Mollusca		
Gastropoda	Omnivore	Generalist

*See Hawkins and Sedell 1981

(Figures 4.4-21 and 4.4-22). Different organisms are dominant during different times of the year or hydrologic periods.

After runoff the community is dominated by collector and filterer mayflies, primarily Travella sp. Mayflies dominate the community into the fall. In late summer, stoneflies emerge and reproduce. Their eggs hatch and young, small stonefly nymphs including Isogenoides sp., Chloroperlidae and Taenionema sp. are numerous in the fall. Members of the family Chironomidae, which are present year-round, become dominant in late fall and over winter, into the spring. Other invertebrates, principally members of the order Trichoptera, are present nearly year-round, but most have patterns that are difficult to discern because of low abundance.

During the period 1981-1983 certain taxa were dominant on the aquatic biology monitoring transects. These included species of Hydropsyche, Isogenoides, Travella, Baetis and members of the family Chironomidae.

Hydropsyche is a net-spinning caddisfly (Order:Trichoptera). Unlike the many caddisfies which build and live in portable cases, Hydropsyche uses silk to construct a retreat fixed to the substrate. The retreat may be fashioned from bits of debris or plant material and it serves as a support for the larva's silken capture net. The capture net is used to trap and filter food particles from the current.

In the White River, Hydropsyche is present year-round and larvae are most abundant in late summer and fall. Most North American caddisflies are univoltine, in general completing a life cycle including five larval instars, pupa and winged adult during a year.

In general, net-spinning caddisflies are detritivore-herbivores collecting food filtered from the water by their capture nets. Some researchers have demonstrated that different genera within the family Hydropsychidae weave meshes of their capture nets with certain dimensions, enabling specialization for food of a particular size range. In Piceance Creek, a headwater tributary of the White River, Gray and Ward (1979) found Hydropsyche to be large particle herbivore-detritivores, primarily, but that larger instars included animals in their diet, usually chironomids. Hydropsyche food habits are known to be highly variable.

Isogenoides is usually the most abundant stonefly (Order:Plecoptera) found in benthic macroinvertebrate samples from the White River. It is likely that this stonefly exhibits a univoltine life cycle like other members of the family Perlodidae. Large numbers of the small, young instars are present each fall, usually beginning in October. Pennak (1978) reports that very few stoneflies have been studied carefully enough to accurately determine duration of the nymphal stages and number of instars. For those known, the number of instars ranges from 12 to 36. Final instar nymphs crawl out of the water onto stones, debris or vegetation prior to emergence. The adult emerges from a dorsal split in the nymphal exoskeleton and adult stoneflies average about one month of longevity in the terrestrial environment.

Stonefly nymphs may also exhibit variability in food habits by species, stage of development, season or time of day. Older instars of Perlodidae are usually predators, feeding on other insects, although smaller instars may be

omnivorous. The nymphs of Isogenoides seem well adapted to large silty rivers - they are the only large Perlodids found in the lower reaches of these streams (Baumann et al. 1977).

During mid-summer, in the White River, Traverella appears as one of the dominant benthic macroinvertebrates in terms of numbers and biomass. These mayflies of the order Ephemeroptera are commonly found on the underside of rocks in riffles. At times, the mature nymphs may occupy certain rocks in densities greater than $100/ft^2$ of surface while most nearby rocks with similar habitat may have only one or two nymphs per square foot (Edmunds et al. 1976). The nymphs move freely about their rock substrate, primarily, by crawling. They are poor swimmers.

The period when aquatic nymphs make the transition to terrestrial winged adults occurs from late August through September in Utah. The emergence of adults occurs at dusk, lasting for a brief period when light intensity falls in the range from five to one footcandles (Edmunds et al. 1976).

Traverella nymphs feed on algae and detritus and are considered to be filter-feeders. The nymphs have some specialized mouthparts (maxillary palpi) that project alongside the head and front of the mouth. These parts have brushy setae which serve to filter small food particles from the current.

Mayflies of the family Baetidae are widespread, being found on all continents and many islands. The family is large, taxonomically, and the genus Baetis contains upwards to 50 species in North America. The many species of Baetis may be adapted to diverse habitats from quiet, slow-flowing

streams to torrential waters.

The nymphs are good swimmers and may move with short darting movements. Moving from spot to spot, they cling with their claws to points of attachment on pebbles and rocks. Facing upstream, their gill-bearing abdomens may swing side to side in the current. In many rivers, the invertebrate drift is largely composed of mayflies, especially Baetis (Brittain 1982).

Baetis species are largely considered collectors of fine-particle detritus. Freely moving, the nymphs locate and feed on surface deposits of detritus and algae. In Piceance Creek, Baetis tricaudatus consumed mostly detritus and some algae with the majority of particles ingested less than 100 microns in dimension (Gray and Ward 1974).

Midges (Family:Chironomidae) comprise a complex and large family of the two-winged flies (Diptera) with more than 2500 species described for North America alone. Adults are usually fragile, non-biting and small (less than 10 mm long) and fly in swarms which may, at times, be large enough to discourage recreation near the bodies of water that support them (Pennak 1978). Chironomids are a difficult taxonomic group and require detailed microscopic examination of head capsules for identification.

Chironomid communites may be composed of diverse and numerous species with representatives of several functional feeding groups present. Lake and streams with as many as 50 species are common and habitats with extreme conditions of temperature, salinity, flow, etc. have the least extensive chironomid fauna.

In the White River, chironomids are abundant year-round and are probably dominated by species which feed on detritus and algae as collectors.

Chironomids are important in the trophic relationships of lotic ecosystems serving as food for many fishes and invertebrate predators as well.

4.4.6 Decomposers

The index of decomposition used for the White River in the aquatic biology monitoring program is the decomposition rate of cottonwood leaves placed in leafpacks in the river. A relationship developed during 1982 (WRSOC 1983) is used for comparison with 1983 data.

The leafpack technique was refined in 1983 to eliminate silt problems. These problems occurred in the past due to horizontal placement of the tubular leafpacks and screening only one end with the other end closed. Prior to 1983, leafpacks had been placed in a calm location near 50 meters on WR18. This lack of turbulence allowed silt to settle into the leafpacks and remain during periods of high suspended solids load. During 1983, leafpacks were placed vertically with screens on both ends. They were located at 22 meters on WR18 in an area of mild turbulence. Silt problems were reduced. Experimental efforts will continue in 1984 to further refine the leafpack technique for monitoring.

Figure 4.4-23 contains the leafpack decomposition relationship developed in 1982. Two data points from 1983 are shown superimposed on this figure. Additional data was collected but the loss of temperature data during the summer of 1983 prevented their use at this time. This data will be obtained from USGS and included at a later date. Both data points appear to fit the previously developed relationship. This lends support to this relationship as a good monitoring tool. Collection of additional data could increase the

strength of this relationship.

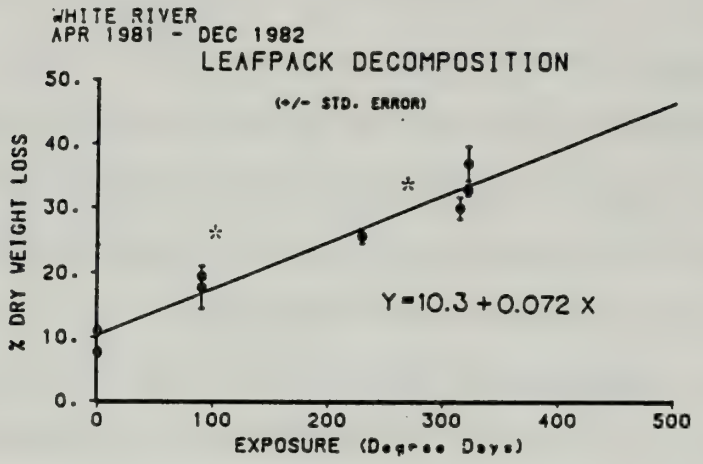

Figure 4.4-23. Leafpack decomposition for leafpacks at Transect WR18 in the White River. Relationship developed from leafpacks placed in the river during October, 1981 to March, 1982. Data shown with an asterisk (*) are for leafpacks in 1983 for which temperature data was available.

4.4.7 Comparisons of Biological Parameters on Control and Treatment Sites

The most important aspect of the aquatic biology program is to monitor for changes in the biology of the White River due to oil shale development. Three transects were selected to provide control and treatment sites for monitoring. Transect WR03 is situated above the oil shale development and is considered to be the control site. Transects WR18 and WR27 are located just below the plant site and downstream approximately five miles from the plant site, respectively. These are treatment sites for Tracts Ua and Ub that should respond if the aquatic ecosystem is being affected by oil shale development at Tracts Ua and Ub.

At the present time, three biological parameters are being used to monitor impacts on the aquatic biology of the White River - the numbers of macroinvertebrates (numbers/m^2), the biomass of macroinvertebrates (mg/m^2) and the amount of chlorophyll *a* (mg/m^2).

The mean of the five samples collected at specific points along each transect are used as data for each parameter.

Two way analysis of variance (ANOVA) techniques were used to test for differences in these parameters by transect and over time. As with many biological parameters, the mean and standard deviation of the estimates of these parameters are related. To meet the assumption of equal variances required by ANOVA, the sample data were transformed. The macroinvertebrate data were transformed using the Ln(x) transformation while the Ln(x+1) was used on the chlorophyll *a* data as zeros were present. This transformation assumes a linear relationship between the mean and standard deviation which

was appropriate for these data.

The hypotheses tested using the ANOVA techniques for each parameter were:

H_{01}: There is no difference in the parameter value at each transect.

H_{02}: There is no difference in the parameter value on each sampling date.

The alternate hypothesis for each of these was that at least two of the samples were significantly different.

Data were selected from all dates where samples were collected from each transect. This included six dates in 1981, five dates in 1982, and eight dates in 1983 for the macroinvertebrate parameters. The same number were used for chlorophyll a except that six sample dates were used in 1982. The varied number of sample dates available is the result of changes in sample design and inaccessibility of the transects due to ice, high water or bad roads.

The results of the two-way ANOVA for the biomass of macroinvertebrates are shown in Table 4.4-6. This analysis shows that the macroinvertebrate biomass differs both by transect and by sampling date.

Multiple comparisons were conducted using Fisher's least significant difference test to determine which transects were different and which dates were different. This analysis showed that Transect WR27 was significantly different from both WR03 and WR18. The analysis by date showed no distinct groups of dates that were separable from each other. Differences, however, were found with samples in early and late August of 1981 being significantly

Table 4.4-6. ANOVA for the biomass of macroinvertebrates.

Source	Degrees of Freedom	Mean Square	F-Value	P-Level
Transect	2	2.717	4.45	.0188
Date	18	2.752	4.51	.0001
Error	36	.610		

higher than most of the other samples.

The results of ANOVA conducted for macroinvertebrate numbers is shown in Table 4.4-7. The numbers of macroinvertebrates were found to differ both by transect and by sample date.

Table 4.4-7. ANOVA for the numbers of macroinvertebrates.

Source	Degrees of Freedom	Mean Square	F-Value	P-Level
Transect	2	1.816	3.90	.0293
Date	18	3.232	6.94	.0000
Error	36	.466		

Multiple comparisons that were conducted using Fisher's least significant difference test showed that WR27 was significantly different from WR03 and WR18. Differences were also found by date but no distinct groupings were found.

The differences found in the numbers and biomass of macroinvertebrates between transects during this three-year period are not surprising. Transect WR27 has been changing from a riffle area to a run over the past two years as described earlier. Analyses conducted in 1981 (ERI 1982) indicated that pool or run areas of the river support considerably fewer macroinvertebrates than nearby riffle areas. The differences found here are consistent with this finding. WR27 appears to no longer be a suitable treatment site for monitoring impacts.

Differences in macroinvertebrate numbers and biomass between sampling dates were expected because of the dynamic nature of the macroinvertebrate community. The community responds to changes in flow, temperature and available food resources, all of which change seasonally.

Because of the seasonal changes in the number and biomass of macroinvertebrates, an analysis was conducted to investigate the similarity in the patterns of these two parameters over time between the control site (WR03) and the treatment site (WR18). A randomization test (Green 1977) was conducted on paired differences in the means of each parameter for each month. The tests showed that there was no significant difference ($p=.10$ for both analyses) in both the numbers and biomass of macroinvertebrates between WR03 and WR18. This indicates that numbers and biomass of macroinvertebrates in both sites are responding similarly.

Table 4.4-8 displays the results of the two-way ANOVA conducted on data of chlorophyll _a_. As was the case with the two macroinvertebrate parameters, differences were found in chlorophyll _a_ amounts between both transects and sampling dates.

Table 4.4-8. ANOVA on chlorophyll a.

Source	Degrees of Freedom	Mean Square	F-Value	P-Level
Transect	2	1.122	5.12	.0107
Date	19	5.457	24.90	.0000
Error	38	.219		

Fisher's least significant difference test was used to determine which transects and dates were significantly different in amounts of chlorophyll a measured. WR27 was found to be significantly different than WR03 and WR18. As with macroinvertebrates, the change in character of WR27 toward a deep, fast run changed the physical nature of the environment away from that found in WR03 and WR18. The deeper, faster water reduced light levels reaching the substrate surface and finer, unstable substrate material reduced the potential for periphyton growth.

Three distinct groupings of dates were found from the multiple comparisons test. The estimates of chlorophyll a during June, July and early August, 1983 were significantly lower than all other sample dates. November, 1982 and late August, 1983 were also significantly different from all other dates. The low values for the summer of 1983 are not unexpected as the high runoff experienced in May, June and July scoured the river bottom, removing most of the periphyton community. Also, high turbidity in the water precluded re-establishment of the algal community until late August.

Parallel to that done for numbers and biomass of macroinvertebrates, a randomization test was conducted on paired differences in chlorophyll a between WR03 and WR18. The test showed that there was no significant difference (p=.883) in amount of chlorophyll a along these two transects. The control and treatment sites are responding quite similarly.

4.4.8 Variability of Biological Parameters Within Transects

An analysis was conducted to investigate relative variance of estimates of three biological parameters from data collected at points along transects as well as at single locations. Reductions in the variance of parameters would increase their sensitivity for monitoring. The three parameters considered in this analysis were numbers and biomass of benthic macroinvertebrates and chlorophyll a contained in periphyton on the river bottom.

Estimates of each of these three parameters have means which are approximately proportional to the standard deviation of the sampled population. Because of this, the estimated standard deviation divided by the estimated mean should be roughly constant for a given parameter collected in a prescribed way. This ratio is often referred to as the coefficient of variation (c.v.). Low c.v. means lower sample variance and more precise estimates for a given number of samples.

In this analysis, the c.v. was calculated for samples collected across the stream as well as for samples collected at single points. Comparisons were then made in the values of the c.v. for single point estimates and cross-stream estimates to see if there were differences. The non-parametric

randomization test (Green 1977) was used to test for differences in the c.v.

Because the physical environment across the stream is not constant, the samples taken at fixed points across the stream are not random samples. It was assumed for this analysis, however, that samples collected from these points were roughly equivalent to random samples taken along the transect. Unfortunately, no validation of this assumption can be made from the available data.

Two separate analyses were conducted for each parameter. The first analysis considered all appropriate sets of samples collected at a single point or at points along a transect during the entire study period (1981 through 1983). Data from Transects WR03 and WR18 were used as they represent the transects used in monitoring.

The results of these comparisons using the randomization test are shown in Table 4.4-9. Both macroinvertebrate parameters showed some reduction in their c.v. when estimated at a single location, however, only invertebrate numbers showed a significant decline. The c.v. of chlorophyll a actually increased when samples were taken from a single point but this difference was not significant.

The second analysis considered samples taken at WR03 in March of 1983. A total of five samples for each parameter were taken at five specific locations across the transect. The c.v. for each parameter at each location is shown in Table 4.4-10.

Table 4.4-9. Results of randomization tests on c.v. for single and multiple location estimates.

Parameter	Single Point c.v. N	Single Point c.v. Mean	Along Transect c.v. N	Along Transect c.v. Mean	P-Level	Significant at a=.05
Invert Biomass	11	.94	37	1.05	.411	No
Invert Numbers	11	.73	37	.95	.033	Yes
Chl *a*	10	1.02	38	.87	.338	No

Table 4.4-10. Coefficients of variation for parameter estimates from WR03 from data collected at single location in March, 1983.

Location Along Transect(m)	Coefficient of Variation Invertebrate Numbers	Coefficient of Variation Invertebrate Biomass	chlorophyll *a*
8	.96	1.39	.13
16	.83	.82	1.48
22	.29	.60	1.33
40	.24	.93	.78
48	.48	.35	.40
Mean	.56	.82	.82

The c.v. was also calculated for the combined samples for the entire transect. These are shown in Table 4.4-11. For all parameters, the c.v. was higher for the estimates along the transect than the mean c.v. calculated for the samples from individual points. The c.v. at some of the locations was higher than the c.v. calculated from samples along the transect, however.

Table 4.4-11. Coefficients of variation for parameter estimates from WR03 for data collected along the entire transect in March, 1983.

Parameter	c.v.
Invertebrate Numbers	.91
Invertebrate Biomass	1.16
Chlorophyll *a*	1.14

Both of these analyses were used to investigate the relative amount of variability incurred when samples are taken at a single location and at several locations along the entire transect. The results of each suggest that there is little difference in the variance of estimates (expressed as the c.v.) between the two sampling methods for these three parameters. No large reductions in the variance can be incurred by one method over another. Thus, the specific objectives of a monitoring program should dictate which sampling procedure is used.

As discussed earlier in this analysis, the samples taken at specified locations along the transect do not represent randomly sampled replicates. As a result they cannot be correctly used as replicates in comparisons between transects or between time periods. Only the mean or other function of the samples for the entire transect can be used for analysis. This reduces the usefulness of five samples to one data point. It is crucial that if cross transect sampling is continued in order to characterize the entire transect that the samples be taken at random points along the transect. If this is done, each sample constitutes a replicate and increases the power of tests considering these data.

Samples taken at single points do not suffer from this problem. They are much more random in nature and in general can be considered to be replicates for analysis.

Other analyses are being conducted to look at similarities and differences among these biological parameters to determine if sampling may be stratified in some manner to allow random sampling while reducing variability.

4.4.9 Use of Controlled Substrates for Benthic Macroinvertebrate Monitoring

The influence of substrate size composition on the distribution of benthic macroinvertebrates has been an area of active study among stream researchers. The focus of some of these studies has ranged from colonization rates of substrate trays and artificial substrates to determinations of microhabitat preferences of various taxa. Patterns observed on natural

substrates by early research resulted in a generalization that larger substrate particle sizes support greater numbers and biomass of stream invertebrates (e.g. Tarzwell 1936; Pennak and Van Gerpen 1947; Ward 1975). As research results from varied environments have accumulated, generalizations such as these have been less demonstrable or even contradicted, and different approaches to the examination of macroinvertebrate distribution have developed.

Studies using introduced substrates have shown rapid colonization rates. Coleman and Hynes (1970) found representatives of nearly all available stream taxa present after 24 hours with all taxa present after three days. They suggest that more than 28 days are needed for full colonization. Allan (1975) found over 50% of numbers and species within artificial substrate trays within 24 hours.

Many studies have investigated the effect of substrate size upon numbers and species richness of invertebrates colonizing the introduced substrates. Results have been mixed and should be interpreted with care. Studies by Wise and Molles (1979) and Khalaf and Tachet (1980) indicated that higher numbers of invertebrates were found in small gravel (10-25 mm) than in other sizes. However, only substrate sizes <10 cm were considered in each study. ERI (1982) in the White River found a secondary peak in invertebrate biomass at substrate sizes of 0.8 to 2.0 cm in the ambient environment with the largest biomass occurring within substrate sizes of 10 cm (Figure 4.4-24). Some studies have shown no effect due to stone size among many taxa (Khalaf and Tachet 1980). Heterogeneity of sizes has increased numbers of taxa found in some instances (Williams 1980) while others have shown the converse (Wise and

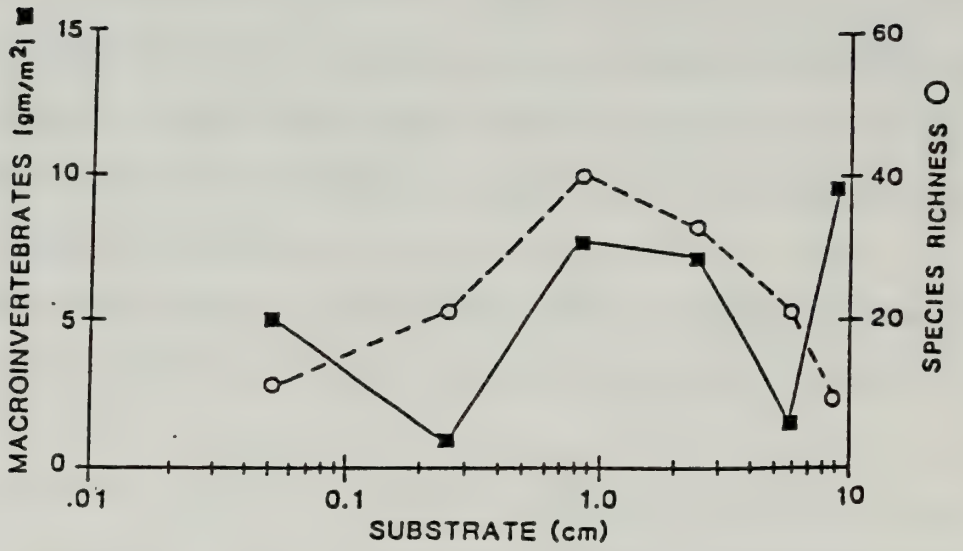

Figure 4.4-24. Biomass and species richness of benthic invertebrates in the White River, Utah as a function of substrate size (ERI 1982).

Molles 1979).

A study combining conventional descriptive methods and experimental manipulations using substratum filled trays was conducted by Minshall and Minshall (1977) in a mountain stream of Idaho. A series of comparisons was made between various combinations of substrate trays in pools and in riffles and hess samples in pools and riffles. Also, some substrate trays had replacements which varied the effects of current velocity. It was found that some species had increases in numbers with increasing velocity (Baetis, Epeorus, Cinygmula, (mayflies) and the beetle larvae Optioservus) and some species decreased with higher velocities (Capnia, Paraleptophlebia, and Ephemerella). In other substrate tray trials it was determined that the absence of a suitable substratum was the main factor in the lack of occurrence of certain riffle fauna in pools.

A related study by Rabeni and Minshall (1977) used similar methods and investigated the effects of detritus and silt in addition to substrate and velocity. They found 39% more organisms in riffle substrates than in pools and the distribution of insects over the range of substrate particle size was similar for both current velocity conditions. Of 16 taxa sufficiently abundant to determine a distributional pattern, three were most abundant in pool substrates (Chironomidae, Capnia, Pericoma), nine in riffle substrates (with three occurring only in riffles) and four evenly found in both. These experiments showed that slow current velocity "does not necessarily inhibit colonization". When suitable substrates were present, mayflies and stoneflies had densities over 3000 per m^2 in pools where they were previously rare or absent. However, as Rabeni and Minshall point out, current velocity

does directly influence substrate particle size. Experiments controlling velocity and testing the effect of a fine (<1mm) coating of silt on the substrates showed variable influences on species composition.

A third experiment suggested that insects responded to amounts of detritus in colonizing different substrates. Experimental results led to the development of a model for insect microdistribution in Mink Creek. The model illustrates that current velocity interacts with other factors to influence distribution. "It sorts and separates the substratum paricles, deposits or carries away silt, transports and shreds leaf detritus and is necessary for organism respiration." Small substrate particles were found to collect large amounts of small detrital particles and larger substrate tended to collect detritus such as twigs and sticks as the dominant fraction. Rabeni annd Minshall concluded that substrate particle sizes determine detritus distribution and that the number of organisms should be directly related to composition of the stream bottom.

During 1983, experiments using introduced substrates were conducted in the White River at Transect WR18. The goal of these experiments was to determine if introduced substrates could be used to reduce variability in estimates of numbers and biomass of benthic invertebrates as compared to benthic samples using conventional sampling methods.

Six substrate baskets approximately 0.5 m in diameter by 15 cm deep were constructed of heavy gage steel hardware cloth. Cobble size stones (10-20 cm) were used as these were shown to be most productive in the White River during 1981 (ERI 1982). It was also felt this size would provide a large amount of silt-free pore space for colonization while smaller sizes would

become clogged with silt.

The baskets with stones from the Logan River, which are more uniformly rounded than those in the White River, were anchored to the river bottom at White River Transect WR18 during July, 1983. The baskets were placed in a group at 22 meters along the transect. This location was selected because of moderate depth and velocities sufficient to keep the baskets silt-free.

The results of these experiments conducted in August through December are presented in Tables 4.4-12 and 4.4-13. Data from substrate baskets is not presented for the December time period due to a change in experimental design. This time period was used to evaluate invertebrate response to available substrate so variable numbers of stones were included in each basket. These results are discussed in later paragraphs.

The variability of numbers and biomass found in substrate baskets was lower than variability across transects (Tables 4.4-12 and 4.4-13). The average coefficient of variation for numbers in samples across transects was 0.99 while that for numbers in substrate baskets was 0.73. Similar results hold for biomass with c.v.'s of 1.04 and 0.73, respectively.

The numbers and biomass of invertebrates found in the baskets were much greater than for equal areas sampled along the transect. This was probably due to more available habitat space in the silt-free baskets.

The November 6 to December 6 period was used to determine if the invertebrates responded to available habitat (number of stones) present in the baskets. The number of stones within a basket was varied from zero to 25 stones in increments of five. Figures 4.4-25 and 4.4-26 present the results of this experiment.

Table 4.4-12. Comparison between numbers and coefficient of variation (C.V.) of samples from introduced substrate and conventional samples from the stream bed. C.V. = S.D./Mean

Sample Date	Numbers across Transect			Numbers in Substrate Basket		
	Mean	S.D.	C.V.	Mean	S.D.	C.V.
830830	390	393	1.008	4447	4186	0.941
831006	842	853	1.013	12207	6543	0.536
831106	1537	1442	0.938	17191	12179	0.708
831206 *	3035	490	0.1614	-	-	-

* Samples taken at a single location on the transect adjacent to the baskets due to ice. Basket data not included due to change in experimental design.

Table 4.4-13. Comparison between biomass and coefficient of variation (C.V.) of samples from introduced substrate and conventional samples from the stream bed.

Sample Date	Biomass across Transect			Biomass in Substrate Basket		
	Mean	S.D.	C.V.	Mean	S.D.	C.V.
830830	485	419	0.864	6251	5569	0.891
831006	220	257	1.168	4951	2658	0.537
831106	550	592	1.076	6242	4668	0.748
831206 *	1056	498	0.472	-	-	-

*Samples taken at a single location on the transect adjacent to the baskets.

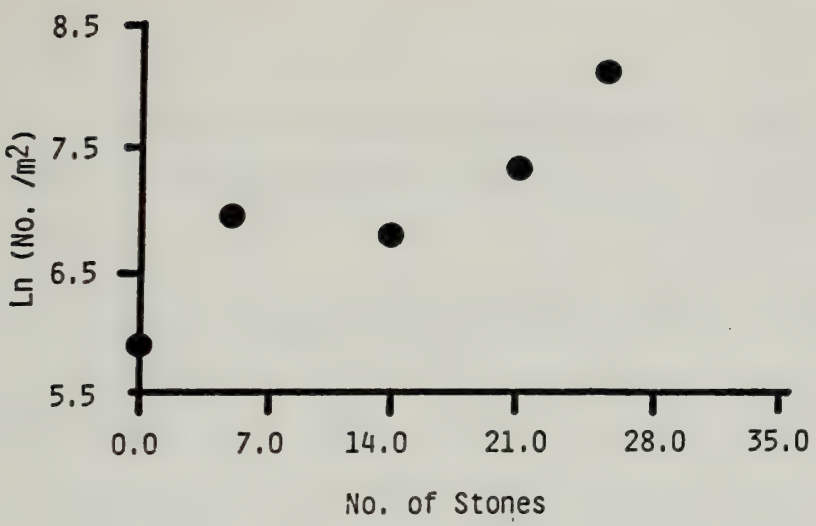

Figure 4.4-25. Numbers of macroinvertebrates (Ln) found per unit surface area in substrate baskets as a function of available substrate (No. of stones).

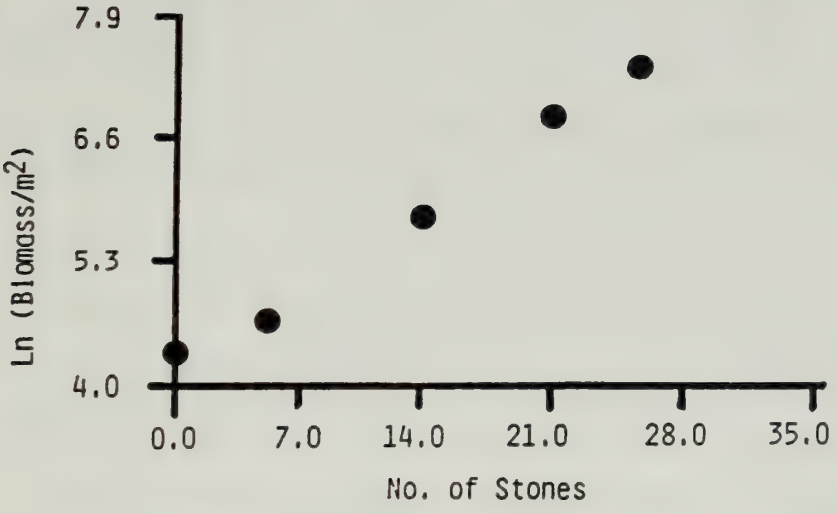

Figure 4.4-26. Biomass of macroinvertebrates (Ln) found per unit surface area in substrate baskets as a function of available substrate (No. of stones).

Both numbers and biomass increased with increasing amounts of available substrate. Regression analyses of both data sets gave the following relationships:

$$Y_1 = 6.09 + 0.0710\ X \qquad R^2 = 0.832 \qquad P = 0.0198$$

$$Y_2 = 4.18 + 0.1180\ X \qquad r^2 = 0.978 \qquad P = 0.0009$$

where:

X = number of cobble size stones in substrate basket

Y_1 = Ln of number of invertebrates /m^2

Y_2 = Ln of biomass of invertebrates/m^2

Analysis of variance conducted on the data showed both relationships were significant.

These relationships are valuable in designing future substrate experiments because they furnish criteria for determining basket size. Further analysis of the data will be conducted to determine if the invertebrates were responding to surface area of stones or interstitial volume.

Substrate baskets as a monitoring tool appear to offer advantages over ambient sampling. They appear to reduce variation inherent in conventional stream sampling techniques. Further experiments will be done with these baskets to evaluate their effectiveness in a control-treatment design between transects. In addition their performance in maximizing species captured will be evaluated.

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TERRESTRIAL FAUNA

5.0 TERRESTRIAL FAUNA

5.1 INTRODUCTION

Abundance and distribution of terrestrial fauna of the Federal Prototype Oil Shale Tracts, Ua and Ub, have been monitored since 1975. During the baseline period, 1975-1981, some faunal components have received more emphasis than others. Amphibians, reptiles, birds, and mammals have been studied in detail since 1975, whereas soil and foliage invertebrates were first sampled quantitatively in 1981, and studies of soil/plant water relations were added to the foliage invertebrate studies in 1983; detailed studies of raptor nesting biology began in 1982; and seed production was studied for the first time in 1983. In 1982 the Environmental Monitoring Manual (WRSOC Monitoring Manual 1982) was prepared to document the sampling of terrestrial fauna during oil shale development and operation so that impacts or enhancement of faunal components could be identified.

The Environmental Monitoring Manual described four Operational Parameters, six Potential Parameters, and two Contingency Parameters used to monitor terrestrial fauna. Based on results during 1983 the parameters will be modified in 1984 to emphasize one Potential and five Operational parameters. Six parameters have been reclassified to contingency status for the upcoming year, 1984 (Table 5.1-1).

Table 5.1-1 Monitoring parameters of terrestrial fauna at the Utah Oil Shale Tracts, Ua and Ub.

Monitoring Program 1984	Monitoring Program 1983
OPERATIONAL PARAMETERS	
1. Breeding Birds	1. Breeding Birds
2. Raptors	2. Spring Migratory Birds
3. Rodents	3. Reptiles
4. Small to Large Mammals	4. Small and Medium-sized Mammals
5. Threatened & Endangered Species	
POTENTIAL PARAMETERS	
1. Foliage Invertebrates	1. Foliage Invertebrates
	2. Soil Invertebrates
	3. Waterfowl
	4. Raptors
	5. Threatened & Endangered Species
	6. Large Mammals (Big Game)
CONTINGENCY PARAMETERS	
1. Chemical Uptake	1. Chemical Uptake
2. Spring Migratory Birds	2. Bats
3. Reptiles	
4. Soil Invertebrates	
5. Waterfowl	
6. Bats	

Four major terrestrial groups were sampled during 1983: foliage invertebrates, reptiles, birds, and mammals. This report on the terrestrial fauna describes the species composition and community characteristics of each group studied, compares these characteristics to the baseline period, and justifies the monitoring status listed in Table 5.1-1. In addition, soil invertebrate studies from 1981 and 1982 were reanalyzed to determine the efficacy of continuing to monitor soil invertebrates. The result was a recommendation to cease soil invertebrate sampling.

As part of the 1983 monitoring program, three detailed studies of the rodent-trapping grids were made. These studies describe: 1) vegetation structure, 2) soil types and their distribution, and 3) seed production by dominant plant species on each grid. The purpose of these studies was to determine how vegetation and soils (habitat characteristics) and seeds (potential food resources) influence the distribution and abundance of rodents among and within the rodent-trapping grids. The soils, vegetation, and seed production of each grid are described in this report. The interrelationships between these parameters and the rodent communities on each grid are discussed in a separate section.

Data collection and management, laboratory and statistical procedures, and analysis and conclusions for terrestrial fauna were conducted by Bio-Resources, Inc. under contract to WRSOC and coordinated by Dr. C. Val Grant.

5.2 SUMMARY

5.2.1 Studies of the Rodent-trapping Grid

Detailed studies of the soils and vegetation were made on 10 rodent-trapping grids. The soil and plant-community types were mapped and described. In addition, seed production by eight dominant perennials and one annual grass was estimated on upland rodent-trapping grids.

Soils on the Juniper grids are generally shallow and very rocky. In Greasewood, soils are sandy to loamy, coarse, and moderately deep to deep. The soils of the Shadscale grids are disimilar; WS-1 has rocky and shallow soils with a shale substratum, whereas WS-4 has moderately deep, somewhat poorly drained soils with numerous sandstone rock outcrops.

Cheatgrass was the most common annual plant among 24 annual species found in samples from the rodent-trapping grid. Annual plants were most abundant in Riparian and decreased in abundance in Greasewood, Shadscale, and Juniper. Perennial plant cover was greatest in Riparian and least in Juniper, whereas ground cover and rock cover were greatest in Juniper and least in Riparian.

Seed production was greatest for cheatgrass (365 to 32,062 seeds/m^2 of ground surface) and big sagebrush (7,677 to 29,257 seed/m^2 of ground surface). Seed production was greatest in the Greasewood sites (especially WG-3) and lowest in Juniper.

5.2.2 Soil Invertebrates

This two-year study (1981-1982) characterizes the nematode and arthropod soil communities. Nematode and arthropod populations fluctuated in response to soil water content, soil temperatures, and vegetation type. Nematode and

arthropod abundances and biomass were greater during the winter when soils were moist and cool. Soil invertebrate abundance was generally greatest in Riparian and least in Juniper. Nematode diversity was greatest in Riparian and least in Juniper, but arthropod diversity was greatest in Greasewood and lowest in Riparian. Nematode and arthropod biomass were correlated with soil water content and soil temperature.

5.2.3 Foliage Invertebrates

There was a significant increase in foliage invertebrates on big sagebrush from 1982 (1,065 ind/m^3) to 1983 (1,398 ind/m^3). Soil water potential in 1983 under big sagebrush and leaf water potential of big sagebrush was lowest in July through September. These water-stressed months generally coincided with the lower levels of foliage invertebrate densities.

Seasonal development of foliage invertebrate faunas on nine host plants are described and related to plant phenology and leaf water potential. In general, the host plants with the greatest leaf water potential (big sagebrush, rubber rabbitbrush, greasewood, and cottonwood) had the greatest densities of invertebrates, but this relationship was somewhat variable (r=0.06 to 0.69). A stronger relationship was evident between leaf water potential of the host plants and richness (r=0.47) and diversity (r=0.43) of invertebrates.

Leaf water potential of big sagebrush was related to the size of its invertebrate faunas in different vegetation types and transects. The order of decreasing leaf water potential was Riparian, Greasewood, Juniper, and Shadscale; the order of decreasing invertebrate densities (ind/m^2) was the same. Correlations (r) between leaf water potential and abundance (ind/m^2), biomass

(mg/m^2), and richness (number of families) for the nine transects were 0.58, 0.74, and 0.86, respectively. Correlations between mean leaf water potential of big sagebrush in the four vegetation types and biomass (mg/m^2) were fairly strong for all functional groups (r=0.63 to 0.99). Grasshopper abundance in the four transects sampled was greatest in WG-1 (34,000/ha), followed by WR-2 (14,000/ha), WS-1 (6,000/ha), and WJ-1 (1,000/ha).

5.2.4 Reptiles

Ten reptile species were recorded on Tracts Ua and Ub. The abundance of some lizards (eastern fence lizards and tree lizards) increased, whereas the abundance of other lizards (sagebrush lizard, side-blotched lizard, and western whiptail lizard) declined. These changes may be linked to annual-plant productivity. For example, the decline in lizard abundance and richness at WG-1 is probably due to the extensive cheatgrass cover that may have limited activity to open areas.

Similarity indices were used to compare reptile faunas on control-treatments pairs of sampling sites. Similarity was greatest between Juniper sites and least between Shadscale sites. WS-4 was more similar to WJ-1 and WJ-5 than to WS-1. The high similarity between WS-4 and the Juniper sites is probably due to physical factors; sandstone outcrops and shallow soils derived from the Uintah Formation appear to be more important than vegetation structure in determining the reptile fauna on WS-4.

Sagebrush lizards and whiptail lizards were absent from WJ-5 in June, a change that was first thought to be an impact due to development at the nearby plant site. To verify this conclusion, WJ-5 was sampled again in August. Both species were present at typical abundance levels indicating that, in fact, there was no impact on the reptile population.

5.2.5 Birds

Five aspects of bird communities were studied: 1) spring birds, 2) breeding birds, 3) waterfowl, 4) raptors, and 5) threatened and endangered species.

As in the baseline period, the spring bird community was dominated by ground foragers. Only a few changes in the 1982 and 1983 spring bird communities were found.

Seventy-six bird species were recorded in June. Consuming biomass of the breeding bird community (excluding raptors, waterfowl, and air-cruising insectivores) in all habitats increased between 1982 and 1983. A dramatic increase in bird density and consuming biomass was recorded in Riparian, due primarily to an increase in insectivores. Bird species richness increased between 1982 and 1983 in all habitats except Shadscale.

Six species of waterfowl were recorded in April 1983 compared to 11 species in April 1982. The Canada goose, green-winged teal, and mallard were the most common species in both years. Decreased waterfowl abundance and species richness in 1983 were probably due to inclement weather just prior to the sampling session.

Twenty active raptor nests were located in 1983 compared to 12 nests in 1982. Golden eagles (seven nests) and red-tailed hawks (seven nests) were the most common breeders in 1983. Breeding success for all species was very high due, very likely, to abundant food (desert cottontails and montane voles) and cool temperatures.

A total of 26 bald eagles were counted during helicopter surveys along the White River in February 1983 compared to 10 eagles in 1982.

5.2.6 Mammals

Thirty-three mammals occurred at Ua-Ub in 1983. Rodent populations did not change significantly at most trapping sites. Rodent richness and diversity increased appreciably in Juniper, and rodent density, richness, and diversity declined in one Shadscale site. Similarity between the Shadscale sites was low compared to the other vegetation types. Montane voles, found only at one sampling site in 1982, occurred on practically every alluvial deposit along the White River, as well as a small population in WG-2 in April and June, 1983. Mule deer were more common in 1983 than in 1982, and bighorn sheep were observed for the first time near Asphalt Wash and near the Ignatio Bridge.

5.3 PROGRAM DESCRIPTION

5.3.1 Objectives

Objectives in 1983, the second year of the development monitoring program, were to identify differences in parameters between the 1975-1981 baseline period and 1983 data. For differences that were identified, a second objective was to determine whether the changes were caused by natural changes in the environment (e.g., precipitation) or were related to tract development activities.

Data from 1983 were also used to evaluate further some potential monitoring parameters in order to assess their efficiencies for monitoring. Several potential monitoring parameters were measured for the first time.

5.3.2 Sampling Locations

Sampling locations are shown in Figure 5.3-1. The nine transects shown were sampled for foliage invertebrates, amphibians, reptiles, birds, and mammals. Rodent populations, annual plant production, and seed production were sampled on nine rodent-trapping grids located near the transects. Precipitation on the tracts from 1975 to 1983 is shown in Figure 5.3.2.

5.3.3 Methods

Methods for most sampling are described in the Monitoring Manual (WRSOC 1982a). Additional methods are discussed below.

5.3.3.1 Studies of the Rodent-trapping Grids. The studies on the rodent-trapping grids in 1983 included: A) soils, B) vegetation, and C) seed production.

SAMPLING LOCATION MAP

Figure 5.3-1 Sampling locations on and near Tracts Ua and Ub. Site designations are: WG, Greasewood; WJ, Juniper; WS, Shadscale; and WR, Riparian. Solid lines are 1-km flushing transects, and squares are rodent-trapping grids.

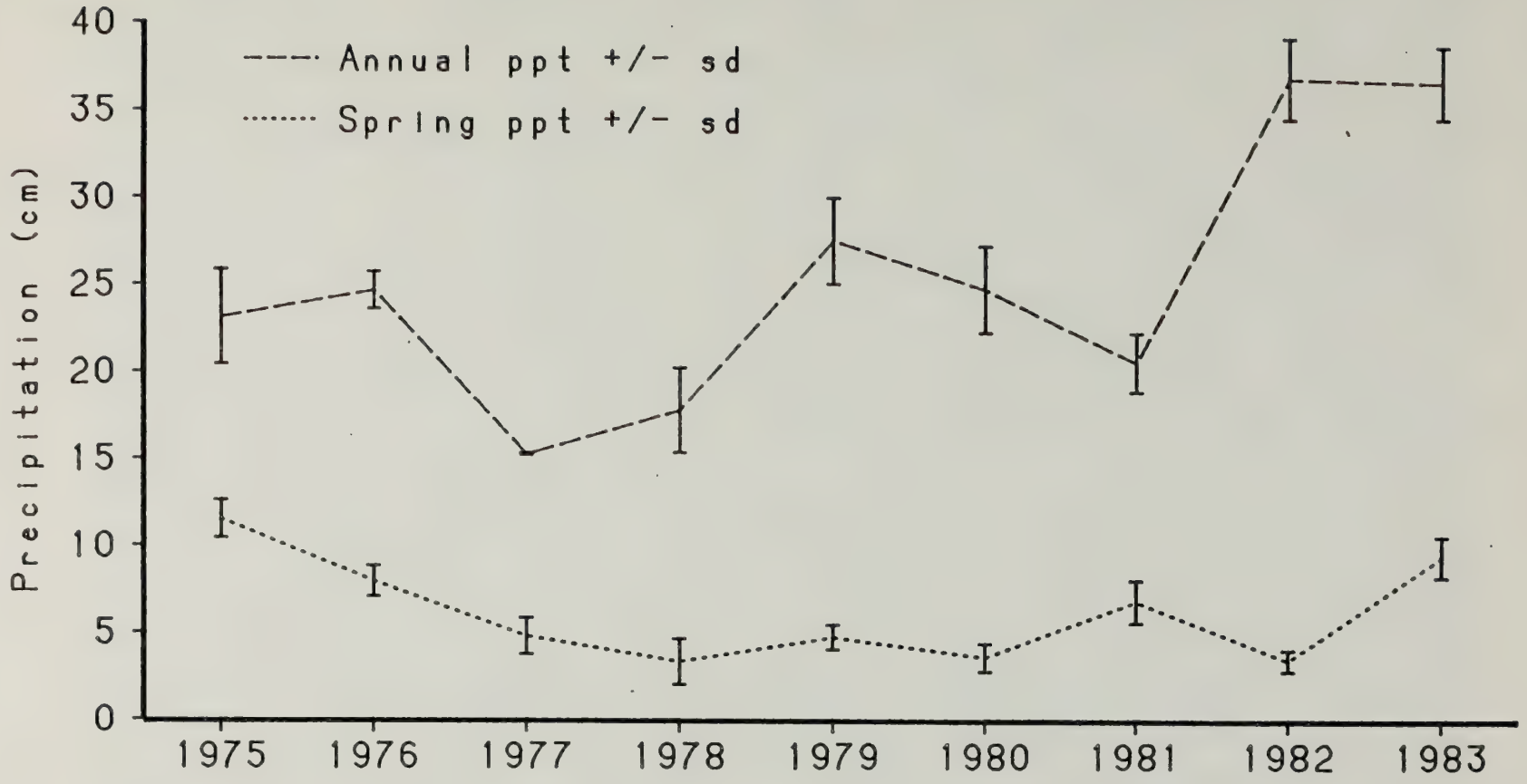

Figure 5.3-2 Annual precipitation (water year) and spring precipitation (April-June) at Utah Oil Shale Tracts, Ua and Ub, from 1975 to 1983.

A. Soil Order 1 soil surveys for inclusive areas of 10 rodent-trapping grids were initiated in spring, 1983. A representative example of each soil type within each grid was selected, and a soil pit 150 cm deep was excavated. Twenty-eight soil profiles were described and classified according to Soil Conservation Service standards and recommendations.

B. Vegetation Annual plants were sampled during June, 1983. Data were collected from thirty 0.25 m^2 quadrats randomly placed throughout each rodent-trapping grid. Mean height and percent cover of annual plant were measured for each quadrat. Annual plants were then harvested, placed in paper bags, oven dried at 55°C, and weighed. A regression equation was developed to express the relationship between annual-plant biomass, height, and cover.

Perennial plants were sampled during October, 1983. Data were collected for thirty 1 m^2 quadrats placed throughout each grid. Percent cover was estimated for the classes: total vegetation, perennial plants, annual plant, rock, litter, and bare ground.

The vegetation types of each rodent-trapping grid were mapped using aerial photography. Vegetation maps were later ground-truthed, and each map was digitized for computer display and analysis. Mapping units were defined based on the dominant species. Mapping units within a grid should not be confused with the assigned vegetation type.

C. Seed Production Seed production by seven dominant shrubs, one tree, and one annual grass (cheatgrass) was sampled on each of the upland rodent-trapping grids as the seeds matured. For the shrubs and trees, seed production was estimated by multiplying the number of seeds produced per flower by

the number of flowers per inflorescence and by the number of inflorescences per plant. Twelve plants (fewer if 12 were not available) of each species occuring on the grid were sampled. The foliage volume of each plant was determined. Seed production is reported as seeds per square meter of foliage.

Cheatgrass seeds were sampled differently. Ten 0.25 m^2, randomly placed plots were clipped on each of the seven upland rodent-trapping grids. After the plant material was oven-dried, the grass was thrashed to remove seeds. The seeds in a weighed subsample were counted, and seed production in the sample was determined by extrapolation from the subsample. Seed production for cheatgrass is reported in seeds per square meter of ground surface.

The number of seeds in the soil was estimated by collecting 12 soil samples from each upland rodent-trapping grid in October. Soil samples were circular samples 4.3 cm in radius and 1.2 cm deep. The soil was sifted through soil sieves in the laboratory. Material that passed through a 0.5 mm soil sieve (USA Standard Sieve #35) was discarded (virtually all seed in the WRSOC flora are larger than 0.5 mm). The remaining material was sorted through a disecting microscope, and seeds were removed and identified. Seeds in the soil are reported as seeds per square meter of soil surface.

5.3.3.2 Foliage Invertebrates Sampling procedures in 1983 differ in three ways from those described in the monitoring manual. First, the sampling method was changed from sweep netting to beat netting. Beat net samples were initiated for big sagebrush and Utah juniper in 1982 and for all other host plants in 1983. Second, the number of sample replicates was reduced from 10 to 8. Third, two important host plants (Fremont cottonwood and black sage-

brush) were added to the sampling program. Data on soil/water and leaf/water relations were collected concurrently with the foliage invertebrate data. Soil water potential (on transects WG-1, WJ-1, WS-1, and WR-2) and leaf water potential on all host plants within transects were analyzed with the use of psychrometers (see Brown and Bartos 1982) from a subset of the foliage invertebrate samples. For each sample of leaf/water potential, approximately ten leaves were picked from a shrub and placed in the psychrometer chamber. Readings were taken after eight to ten hours of equilibration. Psychrometers were also placed in the soil under big sagebrush plants in transects WG-1, WJ-1, WS-1, and WR-2 at depths of 25 and 50 cm. Leaves were picked and soil readings were taken between the hours of 730-930 in May and June. Starting in July pre-dawn measurements were taken. For further information on psychrometry see Brown and Bartos (1982).

Total grasshopper densities, which are not accurately measured with beat or sweep netting, were estimated in August using the quadrat method described in Onsager (1977). Twenty randomly chosen quadrats (0.25 m^2) were selected at evenly spaced intervals along transects WG-1, WJ-1, WS-1, and WR-2. Grasshoppers within each quadrat were counted between the hours of 1230-1530.

5.3.3.3 Birds Migrating birds (April) and breeding birds (June) were censused. Differences between 1983 data and the baseline period are shown graphically by plotting consuming biomass and species richness and showing how these values compare to the 95% confidence intervals for the baseline period.

Known raptor nests were visited in February, April, and June, and new nests were located by extensive ground surveys in April, June, and September,

1983. During these surveys suitable cliffs on and within 2 km of tracts Ua and Ub were searched. During September most nests were photographed and their physical and biological attributes (e.g., aspect, height on cliff, and vegetation type) were recorded.

A bald eagle survey was conducted by helicopter on February 23, 1983. Locations of all bald eagles were mapped.

Abundance of migratory and nesting waterfowl along the White River was sampled by three canoe transects on the White River in April 1983. The numbers and species of waterfowl were recorded and their locations were mapped to the nearest 0.1 mile.

5.3.3.4 Mammals Density of cottontails along each transect was calculated using the computer program "Transect". Details of this technique are described in Burnham et al. (1980). All mule deer sightings within 3 km (rather than 1.6 km as stated in the Environmental Monitoring Manual) of tracts Ua and Ub were recorded and mapped during 1983. Rodents were trapped on nine rodent-trapping grids during August.

5.4 PROGRAM RESULTS AND ANALYSIS

5.4.1 Studies of the Rodent-trapping Grids

This section briefly describes the results of three studies on the rodent-trapping grids: 1) soils, 2) vegetation, and 3) seed production. The interrelationships between these habitat and food-resource characteristics and the distribution and abundance of rodents will be the subject of a future report. In that report, soils, vegetation, and seed production will be described more thoroughly.

5.4.1.1 Soils Map units, comprised of soil types identified in rodent-trapping grids, are listed in Table 5.4-1. Map units are mostly associations of phases of soil series. Two complexes of phases of soil series and miscellaneous land types are also identified. Soil maps with a precision of 5 m^2 were prepared (Figure 5.4-1 through 5.4-4).

The occurrence of map units for rodent-trapping grids are summarized in Table 5.4-2. Soil types with contrasting characteristics which may affect the distribution of burrowing rodents are identified both between different grids of a single dominant vegetation type and within discrete rodent-trapping grids. Also, similar soil types are described within grids of different dominant vegetation type. Potentially limiting soil parameters are summarized by map unit in Table 5.4-3.

The soils of the Juniper trapping grids, WJ-1 and WJ-5, are similar. On moderate to steep convex positions, soils are shallow and very rocky. Rock outcrops are common. Deeper soils occur along wash area.

Table 5.4-1 Map unit legend.

Map Unit Symbol	Map Unit
D	Disturbed
R1	Sandstone bedrock
R2	Shale bedrock
W	Wash
11Kbc	Loamy-skeletal, Lithic Torriorthent, 3-15% slope
12Kd	Fragmental, Lithic Torriorthent, shale substratum, 15-25% slope
13Xde	Fragmental, Lithic Torriorthent/Talus/Rock Outcrop Complex, 25-65% slope
14Xc	Fragmental, Lithic Torriorthent/Rock Outcrop Complex, 5-25% slope
21bc	Coarse-loamy, moderately deep, Typic Torriorthent, 3-5% slope
22b	Coarse-loamy, deep, Typic Torriorthent, 3-5% slope
22Kbc	Loamy-skeletal, deep, Typic Torriorthent, 3-15% slope
31a	Sandy, Typic Torrifluvent, 1-3% slope
32a	Sandy/coarse-loamy, Typic Torrifluvent, 2-3% slope
33ab	Coarse-loamy, Typic Torrifluvent, 2-5% slope
41b	Fine-loamy, Typic Natriargid, 3-5% slope
51b	Coarse-loamy, moderately deep, Typic Camborthid, 3-5% slope
61a	Coarse-loamy, Typic Ustifluvent, 1-3% slope
62a	Sandy, Typic Ustifluvent, 1-3% slope
62a	Sandy, Typic Ustifluvent, 1-3% slope eroded
63a	Coarse-loamy/Fine-loamy Typic Ustifluvent, 0-2% slope
71a	Sandy/fine-loamy/sandy Aquic Ustifluvent 0-3% slope
72a	Sandy Aquic Ustifluvent, 0-3% slope
72a	Sandy Aquic Ustifluvent, 0-3% slope, eroded

Table 5.4-2 Map unit occurrence for rodent-trapping grids.

Map Unit Symbol	WJ-1	WJ-5	WS-1	WS-4	WG-1	WG-2	WG-3	WR-1	WR-2	WR-4
D							X			
R1				X						
R2			X							
W		X			X	X	X			
11Kbc	X	X		X	X	X	X			
12Kd			X							
13Xde		X								
14Xc	X									
21bc			X							
22b			X							
22Kbc	X	X				X	X			
31a							X			
32a					X					
33ab					X	X				
41b				X						
51b				X						
61a									X	
62a									X	X
62a'									X	
63a								X		X
71a										X
72a								X	X	
72a'								X		

Table 5.4-3 Factors limiting the distribution and abundance of burrowing rodents.

Map Unit Symbol	Soil Parameter					
	Depth	Coarse Fragments	Consistence	Drainage	Run-on	Flooding
D						
R1	X					
R2	X					
W						X
11Kbc	X	X			X	
12Kd	X	X			X	
13Xde	X	X				
14Xc	X	X			X	
21bc						
22b						
22Kbc						
31a			X			
32a			X			
33ab						
41b				X		
51b						
61a						
62a			X			
63a				X		
71a			X	X		X
72a			X	X		X

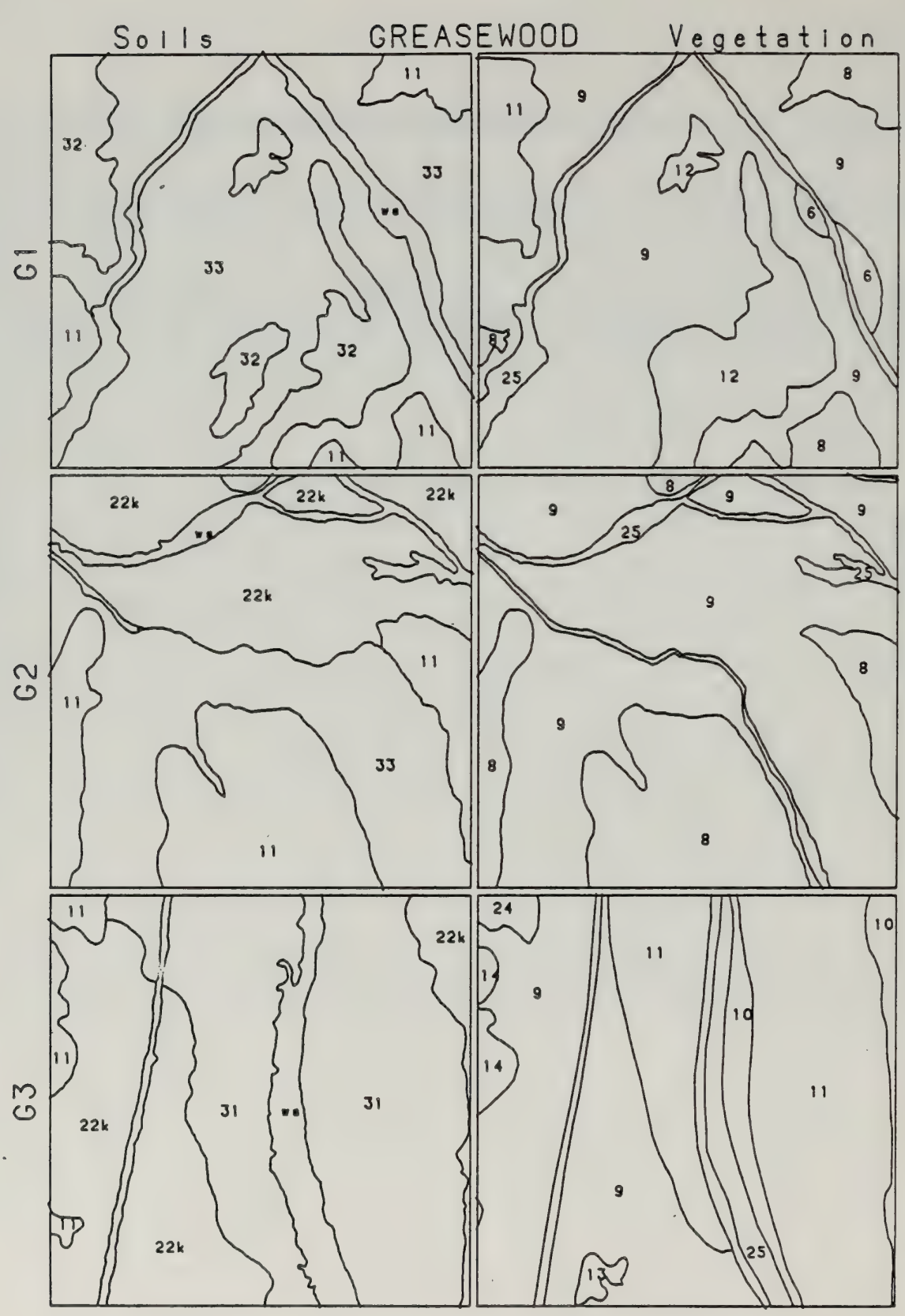

Figure 5.4-1 Soil and vegetation maps of the Greasewood ro ent-trapping grids. Map unit are defined in Tables 5.4-1 and 5.4-7. Scale: 1 inch=60 meters.

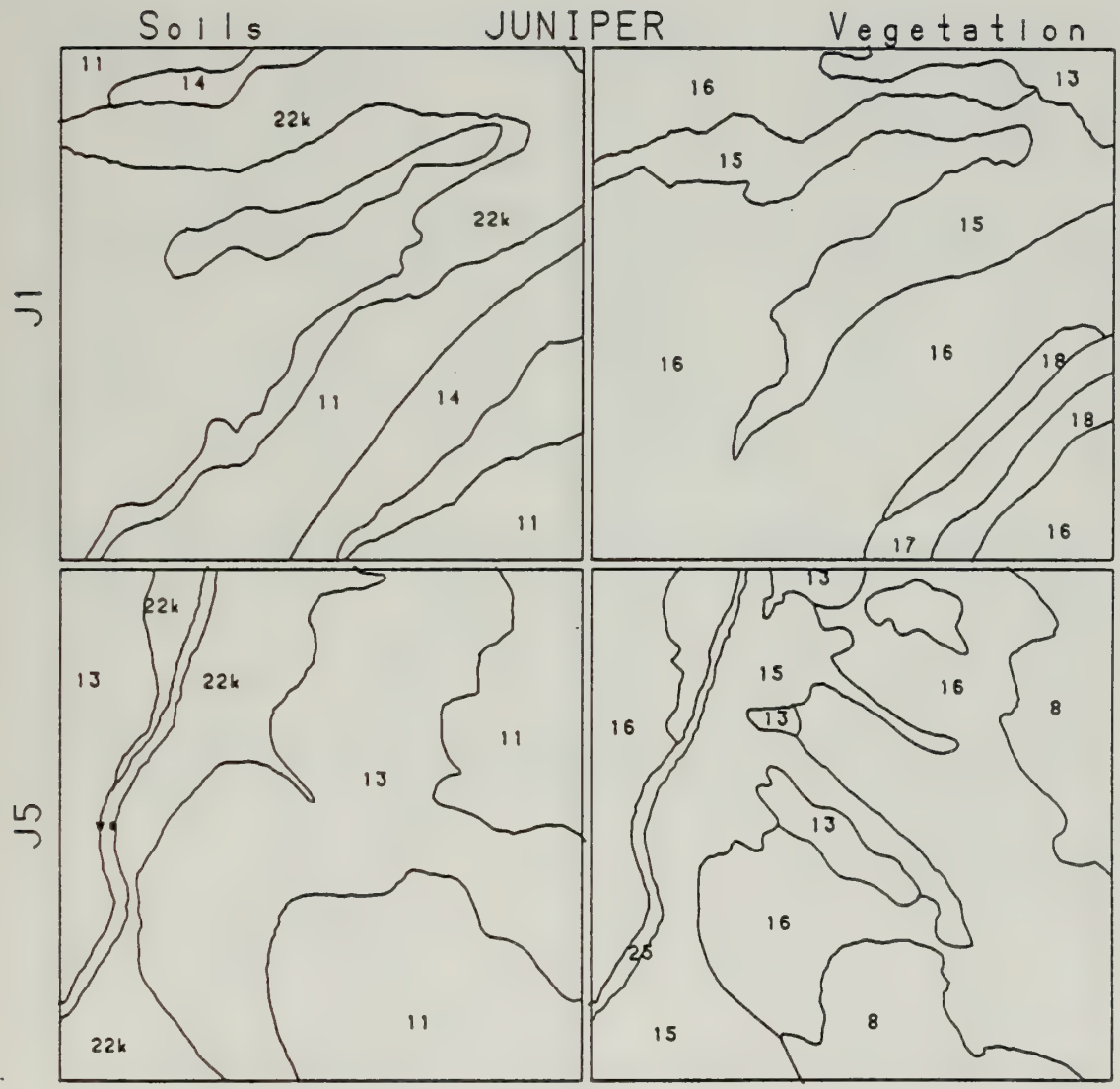

Figure 5.4-2 Soil and vegetation maps of the Juniper rodent-trapping grids. Map unit are defined in Tables 5.4-1 and 5.4-7. Scale: 1 inch=60 meters.

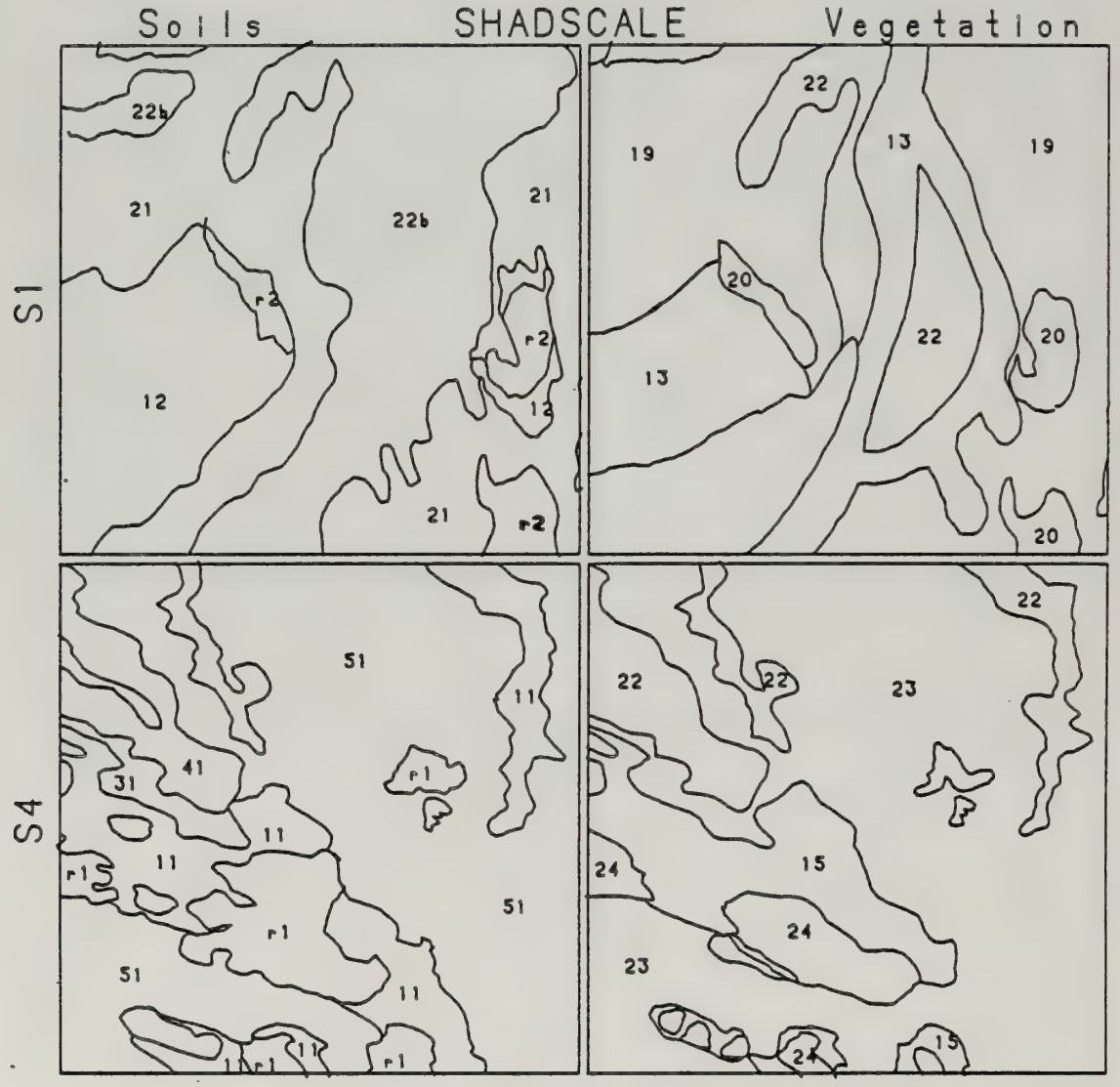

Figure 5.4-3 Soil and vegetation maps of the Shadscale rodent-trapping grids. Map unit are defined in Tables 5.4-1 and 5.4-7. Scale: 1 inch=60 meters.

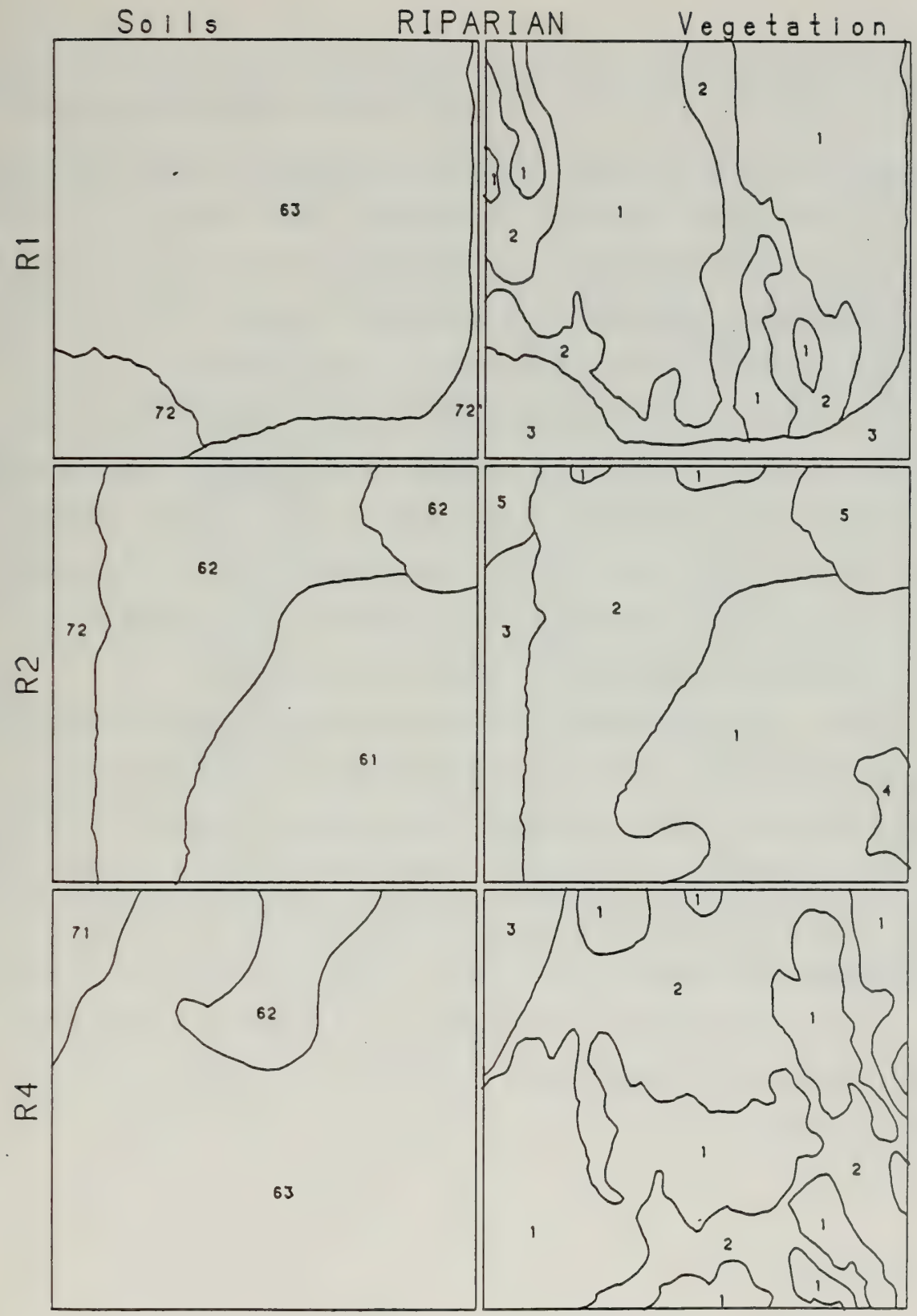

Figure 5.4-4 Soil and vegetation maps of the Riparian rodent-trapping grids. Map unit are defined in Tables 5.4-1 and 5.4-7. Scale: 1 inch=60 meters.

The soils of the Shadscale trapping grids, WS-1 and WS-4, are dissimilar. The soils of WS-1 are as follows: on slopes greater than 15 percent, soils are rocky and shallow to a shale substratum. On slopes less than five percent, soils are coarse-loamy, calcareous, and moderately deep to deep. In grid WS-4 narrow bands of somewhat poorly drained saline and sodic soils are surrounded by moderately deep, somewhat poorly drained soils. Sandstone rock outcrops comprise a significant portion of grid WS-4.

The soils of the Greasewood trapping grids, WG-1, WG-2, and WG-3, are generally similar. Soils are sandy to loamy, coarse, moderately deep to deep, and calcareous on gentle slopes. A small portion of each trapping grid consists of shallow, loamy, rocky soils on slopes ranging from 3 to 15 percent.

The soils of the Riparian vegetation types, WR-1, WR-2, and WR-4, are similar. These flood plain soils are loamy to sandy and deep.

5.4.1.2 Vegetation Cheatgrass is the most common widespread annual plant among 24 annual species found in samples from the rodent-trapping grids. Annual plant cover, height, and biomass varied among the trapping grids (Table 5.4-4); these parameters were greatest in Riparian and least in Juniper. The linear regression equation that best predicts annual-plant biomass is:

(annual plant biomass) =

3.7 * (annual plant cover) + 5.8 * (annual plant mean height).

Annual-plant cover and height account for 92% of the variation in annual-plant biomass ($r=0.96$).

Table 5.4-4 Annual-plant cover, height, and biomass for each of ten rodent-trapping grids in June 1984.

Grid No.	Vegetation Types	Annual Plant		
		Cover (%)	Height (cm)	Biomass ($g/0.25m^2$)
WG-1	Greasewood	34.9	19.8	25.8
WG-2	Greasewood	5.7	10.3	2.7
WG-3	Greasewood	29.8	28.5	34.7
WJ-1	Juniper	2.1	5.6	0.5
WJ-5	Juniper	2.4	6.0	0.9
WS-1	Shadscale	47.1	19.7	18.8
WS-4	Shadscale	2.3	7.7	1.1
WR-1	Riparian	50.9	37.8	39.7
WR-2	Riparian	47.7	50.3	66.6
WR-4	Riparian	38.2	28.5	35.7

The six parameters measured to characterize the perennial-plant communities varied markedly among the vegetation types (Table 5.4-5). Perennial, annual, and total plant cover were greatest in Riparian and least in Juniper. Litter cover was greatest in Riparian and least in Shadscale. Rock cover was greatest in Juniper and least in Riparian. Percent ground cover was lowest in Juniper and highest in Riparian. Annual plant cover in October (Table 5.4-5) was usually less than that measured in June (Table 5.4-4).

The dominant perennial plants are ranked by importance value, which is the sum of relative cover, relative density, and relative frequency in Table 5.4-6. Importance values may range from 0 to 300.

The distribution of vegetation map units on the rodent-trapping grids is shown in Figures 5.4-1 through 5.4-4. Map unit codes for vegetation are defined in Table 5.4-7.

5.4.1.3 Seed Production During 1983 we measured seed production for nine plant species that were dominant elements of the flora on the seven upland (i.e. non-riparian) rodent-trapping grids. Seed production for cheatgrass, spiny hopsage, and spiny horsebrush was measured in June, seed production for shadscale was measured in August, and seed production for big sagebrush, black sagebrush, rubber rabbitbrush, greasewood, and Utah juniper was measured in October.

Table 5.4-5 Percent bare ground, rock, litter, and annual, perennial, and total plant cover for ten rodent-trapping grids in October 1984.

Rodent-Trapping Grid	Vegetation Type	Percent Bare Ground	Percent Cover				
			Rock	Litter	Annual Plant Cover	Perennial Plant Cover	Total Plant*
WG-1	Greasewood	44.6	2.7	12.5	19.5	22.0	40.6
WG-2	Greasewood	41.9	27.2	5.0	2.4	24.1	25.3
WG-3	Greasewood	29.3	0.7	11.6	49.5	10.2	58.7
WJ-1	Juniper	37.1	29.0	9.7	0.6	24.5	24.1
WJ-5	Juniper	47.7	24.0	7.5	0.3	20.7	21.1
WS-1	Shadscale	33.1	11.5	6.8	21.7	27.0	48.4
WS-4	Shadscale	61.7	11.8	6.4	1.5	17.9	19.9
WR-1	Riparian	11.2	0	19.1	59.8	27.9	69.5
WR-2	Riparian	36.9	0	14.9	35.4	24.7	47.8
WR-4	Riparian	8.7	0	30.7	28.2	47.5	60.5

*Total cover may be less than the sum of annual and perennial cover due to plant overlap.

Table 5.4-6 Importance values of the three most dominant plant species within each rodent-trapping grid.

Trapping Grid	Vegetation Type	Species	Importance Value
WG-1	Greasewood	Big sagebrush	98.6
		Greasewood	92.9
		Spiny hopsage	91.2
WG-2	Greasewood	Big sagebrush	105.4
		Black sagebrush	39.1
		Greasewood	31.9
WG-3	Greasewood	Big sagebrush	124.2
		Greasewood	109.9
		Horsebrush	18.4
WJ-1	Juniper	Big sagebrush	106.2
		Black sagebrush	42.0
		Utah juniper	4.1
WJ-5	Juniper	Big sagebrush	71.3
		Black sagebrush	60.9
		Utah juniper	31.2
WS-1	Shadscale	Shadscale	150.3
		Big sagebrush	81.9
		Horsebrush	26.3
WS-4	Shadscale	Big sagebrush	148.0
		Shadscale	76.9
		Greasewood	19.4
WR-1	Riparian	Western wheatgrass	75.1
		Rubber rabbitbrush	63.6
		Fremont poplar	47.6
WR-2	Riparian	Spreading rabbitbr ush	66.9
		Western wheatgrass	62.5
		Fremont poplar	60.3
WR-4	Riparian	Western wheatgrass	161.0
		Fremont poplar	39.7
		Rubber rabbitbrush	38.1

Table 5.4-7 Map unit codes and descriptions for the rodent-trapping grid vegetation maps (Figures 5.4-1 through 5.4-4).

Map Unit Symbol	Map Unit Description
1	Fremont poplar
2	Rabbitbrush-western wheatgrass
3	Five-stamen tamarisk
4	Western wheatgrass - Kentucky bluegrass
5	Spreading rabbitbrush
6	Low rabbitbrush
7	Rubber rabbitbrush-greasewood
8	Black sagebrush
9	Big sagebrush-greasewood
10	Big sagebrush-greasewood (tall)
11	Cheatgrass
12	Greasewood-Cheatgrass
13	Big sagebrush
14	Low rabbitbrush-cheatgrass
15	Utah juniper-big sagebrush
16	Utah juniper-black sagebrush
17	Greasewood-low rabbitbrush
18	Big sagebrush-cheatgrass
19	Shadscale
20	Bull thistle
21	Spiny horsebrush-cheatgrass
22	Shadscale-big sagebrush
23	Big sagebrush-shadscale
24	Rock outcrop
25	Wash area

On the Greasewood rodent-trapping grids, big sagebrush was usually the greatest seed producer (Table 5.4-8) ranging from 145,000 seeds/m^2 of foliage on WG-2 to 694,000 seeds/m^2 of foliage on WG-3. Rubber rabbitbrush was the second largest seed producer ranging from 171,500 seed/m^2 of foliage on WG-2 to 60,000 seed/m^2 of foliage on WG-1. The species that produced the fewest seeds of the seven species sampled on the Greasewood rodent-trapping grids was greasewood which produced only 301 seeds/m^2 of foliage on WG-1 (Table 5.4-8). Cheatgrass, whose seed production in Table 5.4-8 is expressed in different units than the perennial shrubs and trees, produced many more seeds on WG-3 (32,000 seed/m^2 of ground surface) than on WG-1 (8,000 seeds/m^2 of ground surface) and WG-2 (900 seed/m^2).

On the Juniper rodent-trapping grids, only three plant species were sampled. Black sagebrush produced the most seeds (but not as much as big sagebrush on Greasewood or Shadscale grids), and cheatgrass and Utah juniper produced relatively few seeds. Seed production on Utah juniper is slightly overestimated because seeds may persist on the tree for one or more years.

On the Shadscale grids, big sagebrush was again the greatest seed producer (Table 5.4-8). Shadscale produced between 11,000 (WS-1) and 13,000 (WS-4) seed/m^2 of foliage. Cheatgrass on WS-1 produced seeds in quantities similar to those on the Greasewood grids (especially WG-1), but WS-4 produced cheatgrass in quantities comparable to the Juniper grids.

Table 5.4-8 Seed production for eight perennial species (seeds/m^2 of plant foliage) and one annual grass (seeds/m^2 of ground surface) that are dominant on one or more of the upland rodent-trapping grids. Values in parentheses are coefficients of variation (%).

Plant Species	Rodent-trapping Grid						
	WG-1	WG-2	WG-3	WJ-1	WJ-5	WS-1	WS-4
Big sagebrush	345,279 (61.2)	144,980 (86.8)	694,381 (101.2)	-	-	375,087 (63.8)	68,549 (102.2)
Black sagebrush	-	-	-	17,783 (228.8)	33,580 (109.1)	-	-
Shadscale	-	14,059 (118.6)	-	-	-	11,222 (102.4)	12,868 (120.3)
Rubber Rabbitbrush	59,976 (60.1)	171,522 (59.4)	72,889 (98.2)	-	-	-	-
Spiny hopsage	13,005 (139.4)	8,447 (183.6)	16,300 (106.7)	-	-	-	6,183 (127.1)
Greasewood	301 (142.9)	574 (317.6)	1,797 (133.3)	-	-	143 (186.7)	86 (262.8)
Spiny horsebrush	-	2,370 (145.4)	7,036 (72.9)	-	-	4,149 (85.6)	1,213 (103.2)
Utah juniper	-	-	-	201 (147.9)	114 (123.7)	-	-
Cheatgras	8,129 (157.3)	902 (123.8)	32,062 (96.8)	499 (202.8)	365 (253.7)	5,697 (61.1)	421 (193.4)

Coefficients of variation in seed production (Table 5.4-8) for all species on all grids are very high. This indicates great variation in seed production among individual shrubs. Shrubs growing next to each other can differ in seed production by two or three orders of magnitude. This is especially prevalent in dioecious shrubs (e.g., shadscale, spiny hopsage, and greasewood) where male and female flowers are borne on different plants. Thus, in addition to there being a great deal of variation in seed production among vegetation types and among rodent-trapping grids within a vegetation type, there is also great variation in seed production among plants on a grid.

The percent cover of plant species differ on the rodent-trapping grids. To make a valid comparison of seed production among species over a large area (i.e., a rodent-trapping grid), it is necessary to report seed produced per unit of ground area. The seed production data in Table 5.4-9 has been converted to seed/m^2 of ground surface by dividing seed/m^2 of plant foliage by percent cover on the rodent-trapping grid. These data indicate that for the rodent-trapping grids as a whole, sagebrush and cheatgrass are by far the greatest seed producers.

The soil seed reserve was dominated by cheatgrass seeds which comprised 90.8 percent of 5,230 seeds found in 84 soil samples (12 from each of seven upland rodent-trapping grids). Thirteen other species of seeds were recorded including: annual stickweed (Lappula occidentalis), five hook bassia (Bassia hyssopifolia), rabbitbrush sp., shadscale, spiderflower (Cleome sp.), tumbleweed (Amaranthus sp.), greasewood, tansymustard (Descurania sp.), and locoweed (Astragulus sp.). Four uncommon taxa were unidentified.

Table 5.4-9 Seed production (seeds/m^2 of ground surface) for nine plant species that are dominant on one or more of the uplant rodent-trapping grids. Values in parentheses are percent cover within the grids.

Plant Species	Rodent-trapping Grid						
	WG-1	WG-2	WG-3	WJ-1	WJ-5	WS-1	WS-4
Big sagebrush	21,062 (6.1)	13,338 (9.2)	29,164 (4.2)	-	-	29,257 (7.8)	7,677 (11.2)
Black sagebrush	-	-	-	445 (2.5)	1,276 (3.8)	-	-
Shadscale	-	70 (0.5)	-	-	-	1,605 (14.3)	412 (3.2)
Rubber rabbitbrush	60 (0.1)*	343 (0.2)	364 (0.5)	-	-	-	-
Spiny hopsage	962 (7.4)	228 (2.7)	33 (0.2)*	-	-	-	6 (0.1)*
Greasewood	23 (7.8)	15 (2.7)	81 (4.5)	-	-	3 (2.2)	1 (1.0)
Spiny horsebrush	-	36 (1.5)	56 (0.8)	-	-	79 (1.9)	23 (1.9)
Utah juniper	-	-	-	13 (6.3)	7 (5.9)	-	-
Cheatgrass	8,129 (34.9)	902 (5.7)	32,062 (29.8)	499 (2.1)	365 (2.4)	5,697 (47.1)	421 (2.3)
TOTAL	30,236	14,932	61,760	957	1,648	36,641	8,540

*Cover estimated.

Cheatgrass seeds were most abundant on WG-3, WG-1, and WS-1 (Table 5.4-10), the same sites with high annual plant biomass (Table 5.4-4) and high cheatgrass seed production (Table 5.4-9). No cheatgrass seeds were found at WJ-5, and only small amounts were found at WS-4, WG-2, and WJ-1. Variation in seed density was high; the coefficient of variation (CV) was greatest on rodent-trapping grids with the greatest densities of seeds. Frequency, the proportion of samples containing cheatgrass seeds, covaried with mean seed density (Table 5.4-10). This high variability reflects the patchy nature of the soil seed reserve.

Of the 4,746 cheatgrass seeds in samples, 12.5 percent were diseased, 60.6 percent had germinated, and the remaining 26.9 percent were dormant (Table 5.4-10). The diseased seeds had been infected by smut, a type of fungus. These seeds can no longer germinate but might still be eaten by rodents (Rebar and Reichman 1983). The finding that over two-thirds of the seeds had germinated reflects the fact that cheatgrass has a short, variable period of dormancy; some seeds germinate in late summer or fall, whereas other seeds do not germinate until spring.

Table 5.4-10 Germinated, ungerminated, and diseased cheatgrass seeds from soil samples (seeds/m^2).

	Ungerminated			Germinated			Diseased		
Site	Mean	CV	Freq.	Mean	CV	Freq.	Mean	CV	Freq.
WG-1	6,275.7	97.1	91.7	6,714.0	99.1	83.3	3,029.9	112.0	83.3
WG-2	344.3	54.8	50.0	344.3	40.8	33.3	-	-	-
WG-3	8,779.8	83.9	83.3	31,963.0	78.1	100.0	5,057.0	99.2	66.7
WJ-1	258.2	47.1	16.7	172.2	0.0	8.3	-	-	-
WJ-5	0.0	-	0.0	0.0	-	0.0	-	-	-
WS-1	4,507.3	103.0	91.7	4,444.7	138.3	91.7	3,116.0	130.2	83.3
WS-4	430.4	69.3	33.3	975.5	113.5	25.0	516.5	0.0	8.3

5.4.2 Soil Invertebrates

The soil-litter fauna is vital to the energy flow and nutrient cycles of soil ecosystems. Of the invertebrate fauna that inhabits the soil ecosystem, nematode and arthropods are two of the more abundant and functionally important groups. The purpose of this two-year study (1981-1982) was to characterize the nematode and arthropod communities within the soil ecosystem at WRSOC. The study was designed to identify temporal and spatial variations in nematode and arthropod abundance, biomass, trophic structure, and diversity. In addition, several environmental parameters were measured to evaluate potential regulatory controls on nematode and arthropod populations. This study is further described in Barker and Bennett (1983).

Total nematode and arthropod abundance and biomass varied among the vegetation types and with season. Abundance and biomass were greatest in the Riparian vegetation type and least in Juniper. During cool, wet periods, such as winter, nematode and arthropod abundance and biomass were greater than during dry, hot periods.

Percent composition of the biomass was used to characterize trophic group structure. Nematode trophic groups included herbivores, bacterivores, and fungivores. Bactivores accounted for the greatest proportion of the nematode biomass while fungivores accounted for the least. The relative importance of the trophic groups was similar in all vegetation types. Arthropod trophic groups consisted of detritivores, carnivores, omnivores, and herbivores. The detritivore trophic group had the greatest biomass and herbivore trophic group had the least. Similar trophic-group relationships existed in each of the

vegetation types.

Total nematode and arthropod abundance and biomass were significantly correlated ($p<.05$) with several microbial and abiotic parameters. Total nematode abundance and biomass were positively correlated with total bacteria ($r=0.30$), soil respiration ($r=0.45$), total fungi ($r=0.19$), and soil water content ($r=0.25$). Nematode abundance and biomass were negatively correlated with soil temperature ($r=0.19$). Total arthropod abundance and biomass were positively correlated with percent water content ($r=0.25$) and soil temperature ($r=0.22$).

Nematode species diversity fluctuated among the vegetation types and through time. Species diversity was greater in Riparian and Greasewood than in Shadscale or Juniper. Low species diversity was observed in June and August; December had high species diversity.

Arthropod species diversity also fluctuated among the vegetation types and months. Species diversity was highest in Greasewood and Shadscale and lowest in Riparian. June was the month with the lowest diversity, whereas diversity was the highest in February.

The fluctuations in nematode and arthropod populations are probably in response to soil water content. Soil moisture is usually high from late fall to early spring. As the days become warmer, soil moisture decreases. Nematodes are sensitive to soil moisture. As the soil dries, less water is available to sustain nematode activity. Arthropods are not as sensitive to soil water content as nematodes. However, nematodes are a prey source for arthropods. Therefore, as nematode populations increase or decrease in

response to soil water moisture, arthropods should fluctuate similarly.

The high variability of both nematode and arthropod density during this two-year study as well as the time lag required to process samples render these parameters inappropriate as monitoring tools.

5.4.3 Foliage Invertebrates

In 1983, three changes were incorporated in the foliage invertebrate studies. The first change was to conduct studies of soil water relations concurrently with the foliage invertebrate studies. Water relations are considered one of two major "driving forces" in the functioning of desert ecosystems (the other being nitrogen) and are central to the biology of desert plants (MacMahon and Schimpf 1981). Thus, information on water relations is important in the explanation of differences in foliage invertebrate productivity among years, vegetation types, months, and possibly host plants. The foliage invertebrate studies will provide more answers to "cause-effect" questions.

Second, grasshopper (Orthoptera: Acrididae) densities were more accurately estimated. It is important to measure this group because it can be quite destructive to desert plants (Parker 1982), and as such may interfere with revegetation processes.

Finally, the beating method of sampling was incorporated, providing a much more quantitative sample and lower variability.

5.4.3.1 Overall Trends The foliage invertebrates are dominated by herbivores, the sap-feeders and leaf-chewers (Table 5.4-11). Important sap-feeders are Cicadellidae (Empoasca sp., Acertatagallia sp.), Miridae (Europiella sp, Phyllopidea sp.), Coccoidea, Thripidae, and Aphididae. Important leaf-chewers are the Lepidoptera and Coleoptera. Saprophores are dominated by the Oribatidae (Eporibatula sp.). Predators are mostly spiders (Araneida) and true bugs (Anthocoridae, Nabidae). A complete list of taxa and tables of foliage invertebrate densities, richness, and diversities according to host plant (within transect) are available from Bio-Resources, Inc. Table 5.4-12 gives the sampling schedule for 1982 and 1983.

Major differences in invertebrate populations in 1982 and 1983 were related to moisture conditions. A very wet spring in 1983 (9.3 mm of rain; Figure 5.3-2), compared to 1982 (3.5 mm) resulted in noticeably greater April soil moisture in 1983 than in 1982 (Figure 5.4-5). After July, soil moisture did not differ greatly between 1982 and 1983. The major differences in invertebrate abundance (ind/m^3) on big sagebrush, the only plant sampled on all transects in both 1982 and 1983, occurred between April and June, the period when soil moisture was greater (Figure 5.4-5). Similarly, greater family richness on big sagebrush occurred in April through June of 1983 than during the same period of 1982; after this time, there were no major differences (Figure 5.4-6). Mean values (April-October) of richness on big sagebrush were approximately the same for 1982 (30.7 families) and 1983 (31.7 families) as were means for diversity (1982, mean=1.95; 1983, mean=1.98). However, biomass (mg/m^3) was consistently greater during all months of 1983.

Table 5.4-11 Total individuals of foliage invertebrate in 9 functional groups sampled with beat net in 1982 and 1983. See Table 5.4-12 for details of sampling schedule.

Functional Group	1982	1983
Sap-feeders	45,976	56,209
Leaf-chewers	3,772	8,192
Saprophores	3,948	9,045
Predators	3,307	4,873
Parasites	1,592	2,259
Omnivores[1]	774	1,247
Various Diptera[2]	665	1,941
Flower feeders	152	241
Non-feeders	143	1,151
TOTAL	60,329	85,158

[1]Hymenoptera:Formicidae (ants).
[2]Difficult to assign to functional groups, but most are saprophores.

Table 5.4-12 Summary of monthly sampling schedule of foliage invertebrates in 1982 and 1983. Number of replicates for host plant (within transect), plant water potential, and soil water potential are shown in parentheses. Also shown are months when water potential measurements were taken. Samples were taken with a beat net.

Vegetation Type	Transect	Host Plant(8-10)	Water Potential[2] Plant(2-5)	Soil(6)[3]
Greasewood	WG-1	Big Sagebrush	May-Oct	May-Oct
		Rubber Rabbitbrush[1]	May-Oct	
		Greasewood[1]	May-Oct	
	WG-2	Big Sagebrush	May-Oct	
		Greasewood[1]	May-Oct	
		Spiny Hopsage[1]	May-Sep	
	WG-3	Big Sagebrush	May-Oct	
		Greasewood[1]	May-Oct	
		Spiny Hopsage[1]	May-Sep	
Juniper	WJ-1	Big Sagebrush	May-Oct	May-Oct
		Black Sagebrush[1]	May-Oct	
		Utah Juniper[1]	May-Sep	
	WJ-5	Big Sagebrush	May-Oct	
		Black Sagebrush[1]	May-Oct	
		Utah Juniper[1]	May-Oct	
Shadscale	WS-1	Big Sagebrush	May-Oct	May-Oct
		Shadscale[1]	May-Sep	
		Spiny Horsebrush[1]	May-Jul	
	WS-4	Big Sagebrush	May-Oct	
		Shadscale[1]	May-Sep	
		Spiny Horsebrush[1]	May-Jul	
Riparian	WR-2	Big Sagebrush	May-Oct	May-Oct
		Rubber Rabbitbrush[1]	May-Oct	
		Cottonwood[1]	May-Sep	
	WR-4	Big Sagebrush	May-Oct	
		Rubber Rabbitbrush[1]	May-Oct	
		Cottonwood[1]	May-Sep	

[1]No beat samples taken in 1982.
[2]Initiated in 1983.
[3]Includes two depths of soil water potential: 25 and 50 cm.

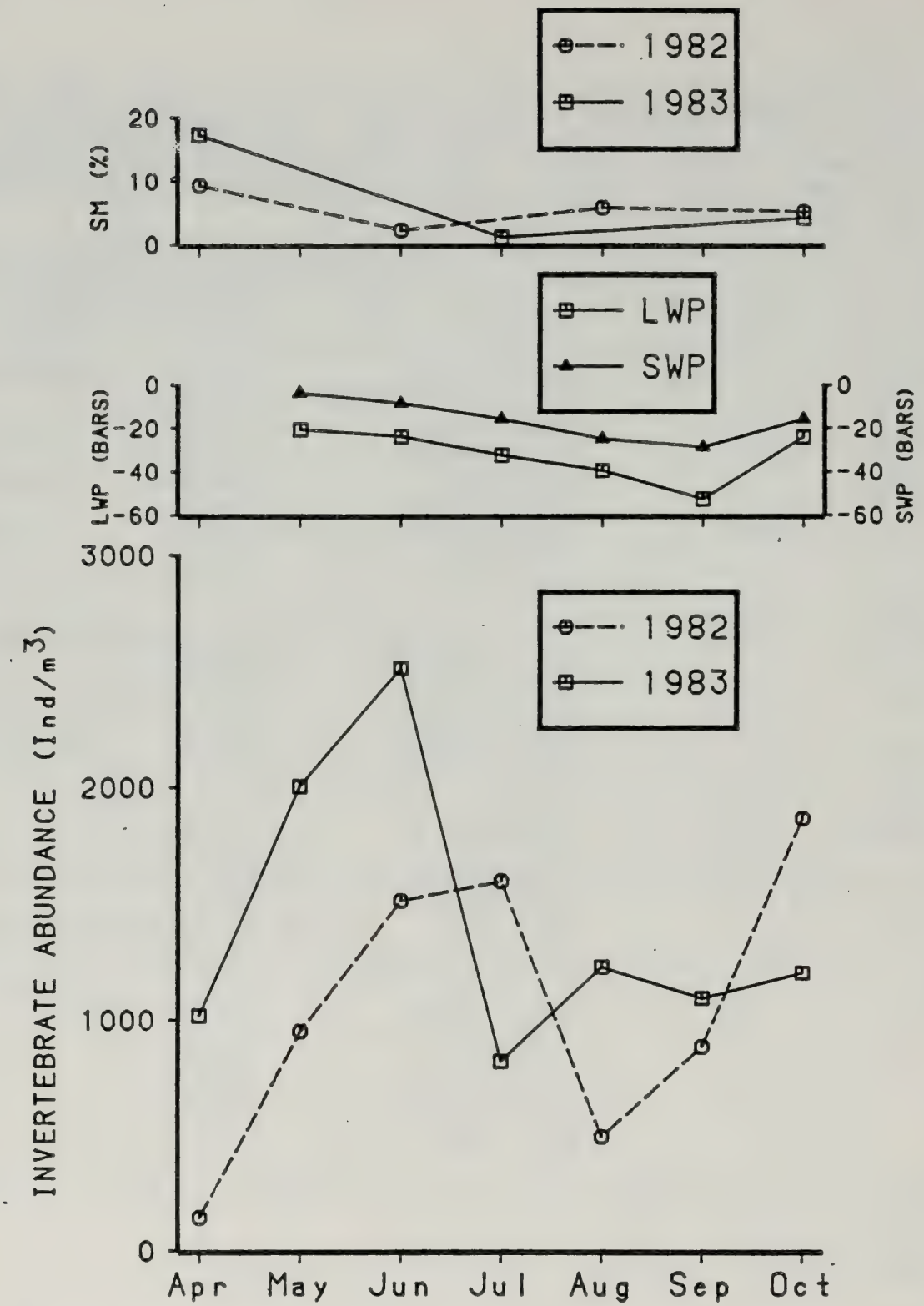

Figure 5.4-5 Abundance (ind/m^3) of all foliage invertebrates on big sagebrush in 1982 and 1983, leaf water potential (bars) of big sagebrush in 1983, soil water potential (bars) under big sagebrush in 1983, and soil moisture (%). Abundance data are means of nine transects. Soil moisture data were collected by Native Plants, Inc.

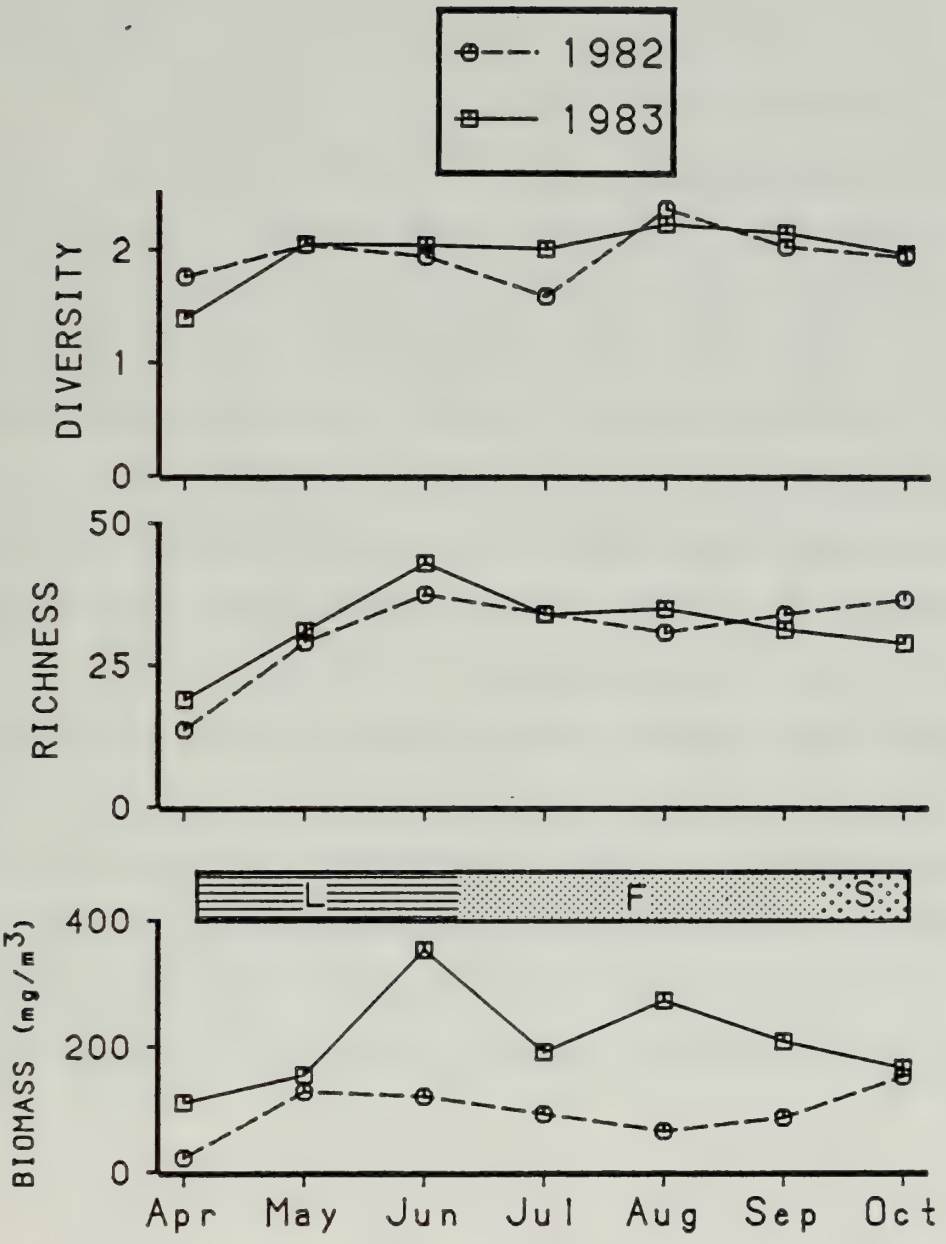

Figure 5.4-6 Biomass (mg/m^3), richness (R = number of families), and diversity (H') of foliage invertebrates on big sagebrush in 1982 and 1983. Data are means of 9 transects. Also shown is gross plant phenology depicting leaf (L), flowering (F), seed (S), and leaf drop (D) stages.

The seasonal pattern of change in water potential (Figures 5.4-5) demonstrates that the water-stressed months, July through September, generally have the lower levels of invertebrate densities. This relationship can probably be extended to explain changes over years.

5.4.3.2 Host Plant Species As was the pattern with big sagebrush (Figures 5.4-5 and 5.4-6), invertebrate densities on the various host plants were generally related to the seasonal pattern of change in leaf water potential and growth (Figures 5.4-7 through 5.4-10). Those host plants that maintained higher leaf water potentials throughout the season (rubber rabbitbrush, cottonwood, big sagebrush, and greasewood) also supported greater densities of invertebrates (Figures 5.4-5, 5.4-7, and 5.4-8). These same host plants had longer leaf stages and later flowering and seed production; thus, they supported greater densities of invertebrates in late summer to autumn. Correlations (r) between mean leaf water potential of the nine host plants were weak for the three abundance measures (0.06 to 0.27) but were much stronger for the three biomass measures (0.11 to 0.60; Table 5.4-13). Host plants with higher leaf water potentials also supported greater numbers of families (Figures 5.4-9 and 5.4-10); the correlations were 0.47 and 0.43 between leaf water potential and richness and diversity, respectively (Table 5.4-13).

Table 5.4-13 Mean values of water potential and invertebrate abundance, biomass, richness (R), and diversity (H') on 9 host plants from May to October, 1983. Correlation coefficients are shown for linear regressions between leaf water potential and the faunal characteristics.

Host Plant	Plant Water Potential (bars)	Abundance			Biomass			R	H'
		#/m^3	#/m^2	#/Shrub	mg/m^3	mg/m^2	mg/Shrub		
Big sagebrush	-32.4	1475.9	314.0	122.9	223.9	53.3	21.0	34.1	2.07
Black sagebrush	-37.8	6576.6	346.2	39.3	609.3	35.0	4.1	16.3	1.40
Rubber rabbit-brush	-17.1	532.7	111.8	55.2	69.2	43.7	21.1	33.8	2.39
Greasewood	-31.8	377.4	78.1	41.1	114.3	41.7	16.3	29.3	2.33
Spiny Hopsage	-45.0[1]	448.2	67.3	29.7	216.0	28.7	16.0	18.8	1.51
Spiny Horsebrush	-44.5[2]	648.9	105.5	24.1	97.7	17.5	4.1	18.0	1.25
Shadscale	-63.0[1]	790.9	81.3	11.5	209.5	28.8	4.0	18.4	2.15
Utah Juniper	-41.1[1]	346.8	93.3	12.8	105.1	33.2	3.8	18.6	1.90
Cottonwood	-17.4[1]	317.0	83.1	7.1	447.6	184.5	16.5	17.3	2.22
Correlation (r)		0.06	0.09	0.27	0.11	0.60	0.69[3]	0.47	0.43

[1]May - September only.

[2]May - July only.

[3]$p<0.05$

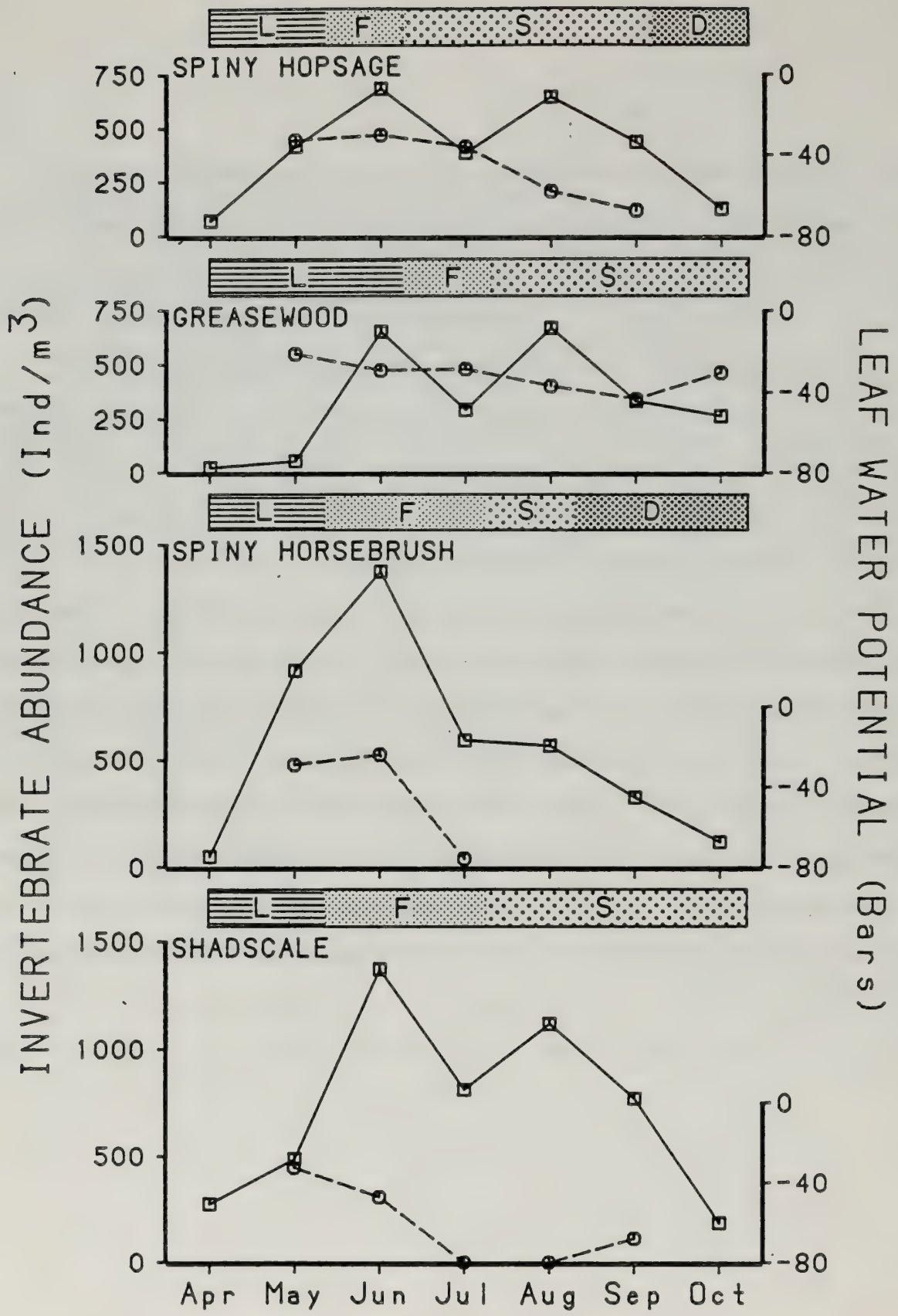

Figure 5.4-7 Abundance (ind/m^3) of all foliage invertebrates on host plants spiny hopsage, greasewood, spiny horsebrush, and shadscale in 1983. See Figure 5.4-6 for details of phenology graphs.

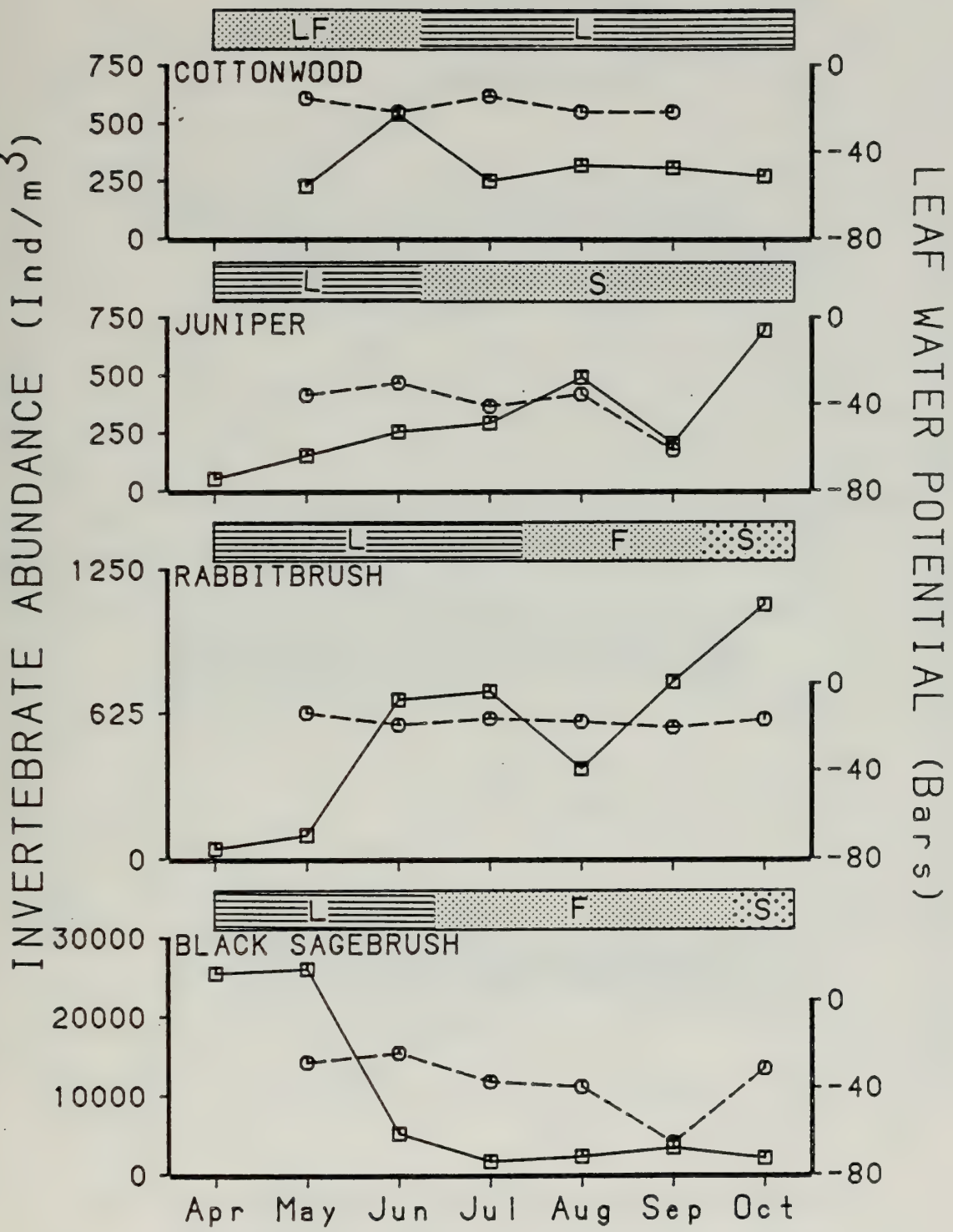

Figure 5.4-8 Abundance (ind/m^3) of all foliage invertebrates on host plants cottonwood, Utah juniper, rubber rabbitbrush, and black sagebrush in 1983. See Figure 5.4-6 for details of phenology graphs.

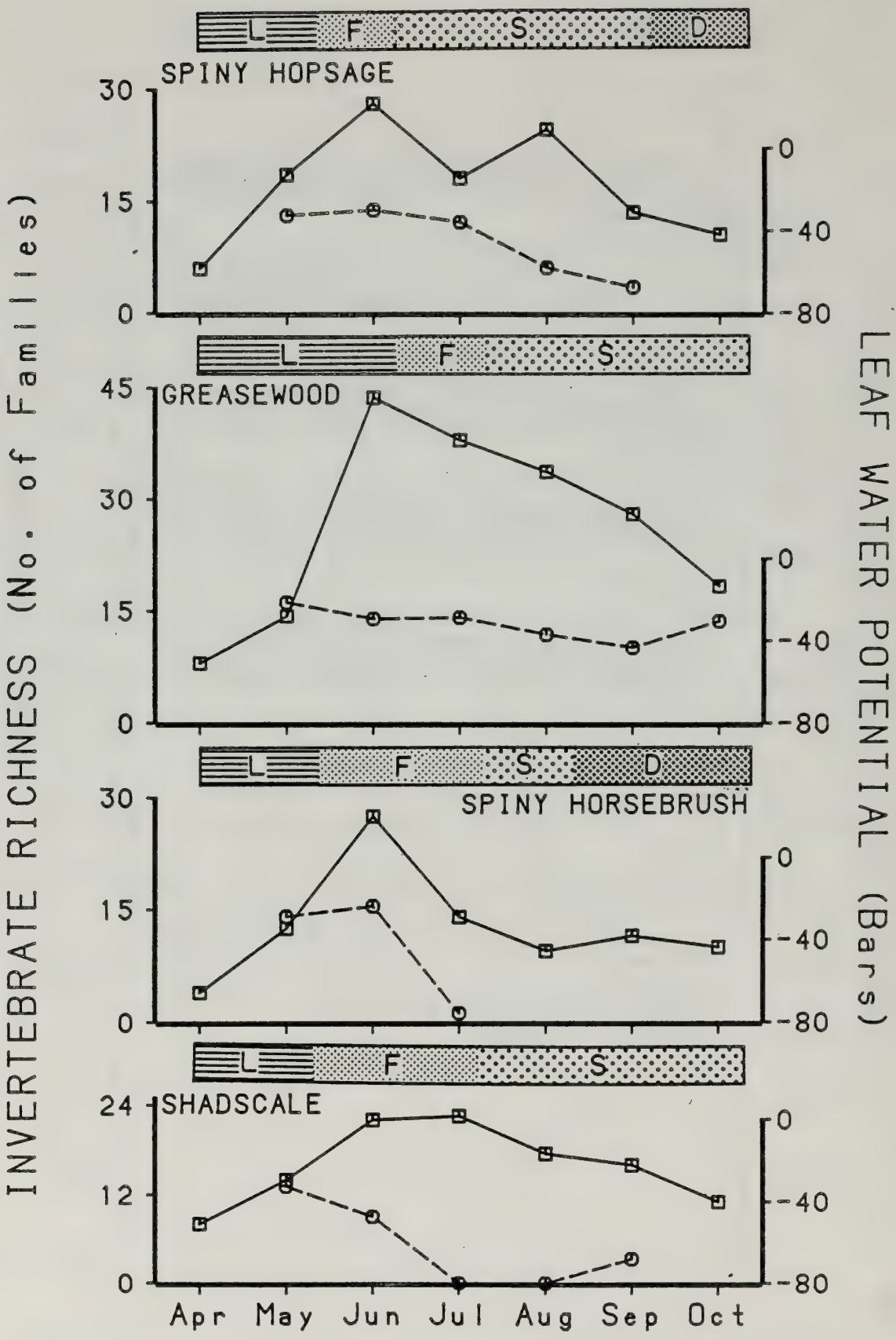

Figure 5.4-9 Richness (number of families) of all foliage invertebrates on host plants spiny hopsage, greasewood, spiny horsebrush, and shadscale in 1983. See Figure 5.4-6 for details of phenology graphs.

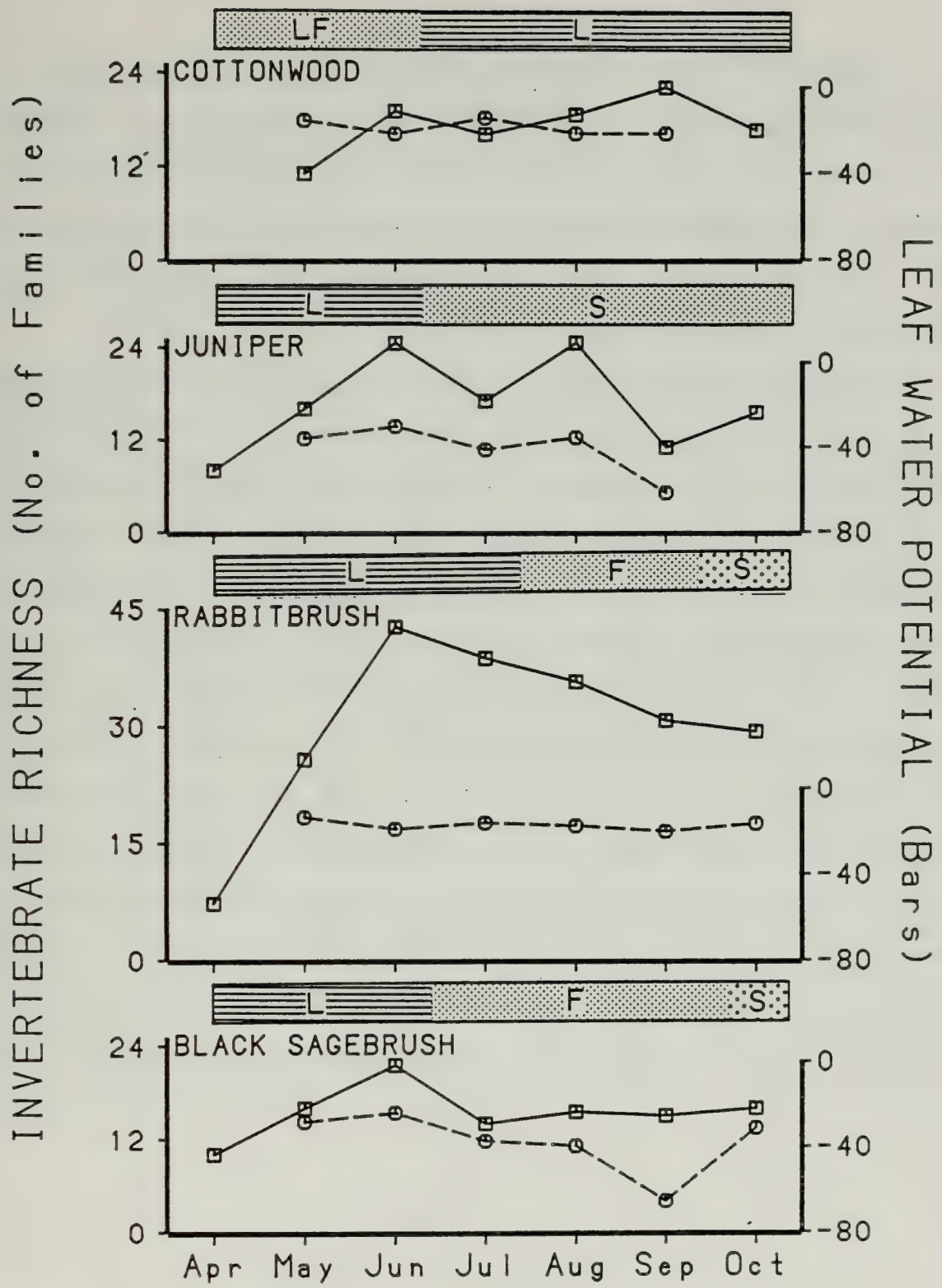

Figure 5.4-10 Richness (number of families) of all foliage invertebrates on host plants cottonwood, Utah juniper, rubber rabbitbrush, and black sagebrush in 1983. See Figure 5.4.6 for details of phenology graphs.

Rankings of host plants by the size of their invertebrate faunas can vary somewhat depending on the measure used (Table 5.4-13). For instance, invertebrate densities per volume (ind/m^3) for black sagebrush can become quite inflated compared to densities per cover (ind/m^2) since black sagebrush is a low-growing shrub. Table 5.4-13 compares several density and biomass measures.

5.4.3.3 Vegetation Types All three upland habitats showed a significant increase in invertebrate abundance on big sagebrush from 1982 (815 ind/m^3) to 1983 (1,468 ind/m^3). Greasewood vegetation type in particular showed a very large increase in abundance (Figure 5.4-11). Riparian, however, showed a 50 percent reduction in invertebrate abundance between 1982 (2,021 ind/m^3) and 1983 (1,035 ind/m^3). The upland sites also showed a marked increase in biomass in 1983 (Figure 5.4-12). Increases in richness between 1982 and 1983 were noticeable for Greasewood and Riparian (Figure 5.4-13). However, as with certain host plants, the measure used for density may affect some of the conclusions. The relative rankings of invertebrate faunas on big sagebrush in the three upland vegetation types were unaffected by the measure used, but the ranking of host plants in Riparian was affected (Table 5.4-14). The use of volume in abundance (ind/m^3) on biomass (mg/m^3) estimates tended to deflate values for Riparian because shrubs in that vegetation type are usually much taller.

Table 5.4-14 Mean values of water potential for big sagebrush, and invertebrate faunal characteristics for big sagebrush from May to October, 1983. Values for vegetation types are means of transects (within vegetation type). Correlation coefficients are shown for linear regressions between leaf water potential and the faunal characteristics.

	Water Potential (bars)	Abundance			Biomass				
	Plant (soil)	#/m^3	#/m^2	#/shrub	mg/m^3	mg/m^2	mg/shrub	R	H'
Vegetation Type									
Greasewood	-34.4	2101.0	383.9	189.7	270.0	58.7	31.7	34.8	1.97
Juniper	-37.9	1206.4	159.9	51.8	221.6	36.7	12.6	30.2	2.12
Shadscale	-39.5	1060.6	134.9	48.2	168.1	29.2	10.1	30.2	2.36
Riparian	-15.6	1214.9	426.7	167.9	186.3	85.8	31.9	39.5	1.89
Correlation (r)		0.06	0.79	0.63	0.19	0.95	0.72	0.95	-0.76
Transect									
WG-1	-37.5 (-18.6)	1463.5	314.9	113.5	267.1	62.3	22.7	32.5	1.92
WG-2	-33.5	1243.9	214.3	81.9	190.1	37.6	14.1	33.2	2.16
WG-3	-32.3	3612.0	622.6	373.7	308.8	76.2	47.8	38.7	1.83
WJ-1	-37.6 (-16.5)	1063.1	154.2	51.6	233.1	34.2	12.5	28.7	2.08
WJ-5	-37.1	1349.8	165.5	52.9	269.0	39.1	12.6	33.3	2.17
WS-1	-35.6 (-20.4)	1058.5	142.3	53.6	216.8	31.1	10.9	31.0	2.53
WS-4	-43.5	1062.6	127.5	42.9	130.5	27.0	9.3	29.3	2.19
WR-2	-12.6 (-11.0)	1275.0	393.3	164.5	163.7	70.0	30.9	40.8	1.96
WR-4	-18.7	1154.7	460.0	171.2	227.0	101.6	32.8	38.2	1.83
Correlation (r)		0.00	0.58	0.40	0.12	0.74*	0.58	0.86*	-0.46

*$p<0.05$

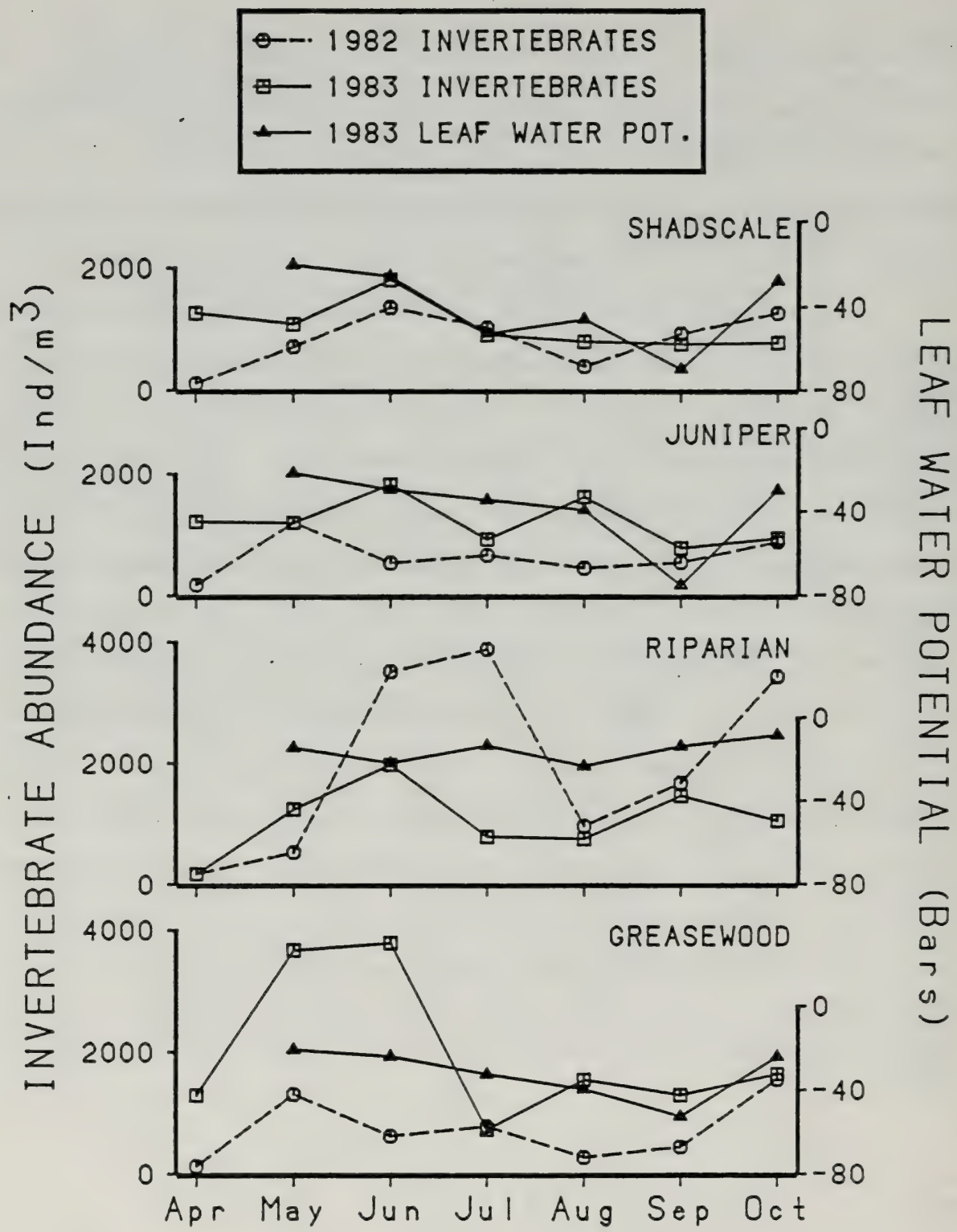

Figure 5.4-11 Abundance (ind/m^3) of all invertebrates on big sagebrush in four vegetation types in 1982 and 1983 and leaf water potential (bars) of big sagebrush in four vegetation types in 1983.

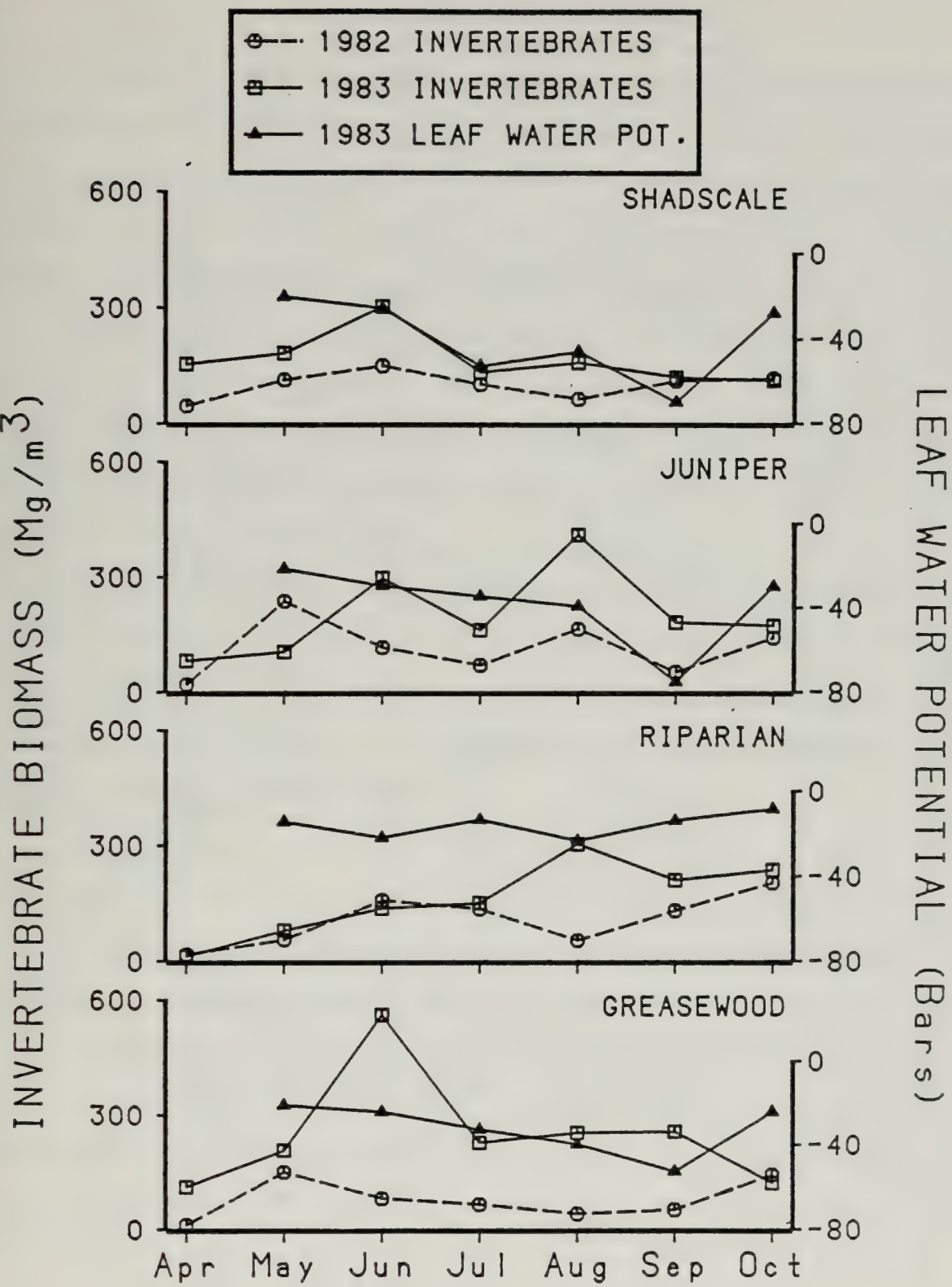

Figure 5.4-12 Biomass (mg/m^3) of all invertebrates on big sagebrush in four vegetation types in 1982 and 1983 and leaf water potential (bars) of big sagebrush in four vegetation types in 1983.

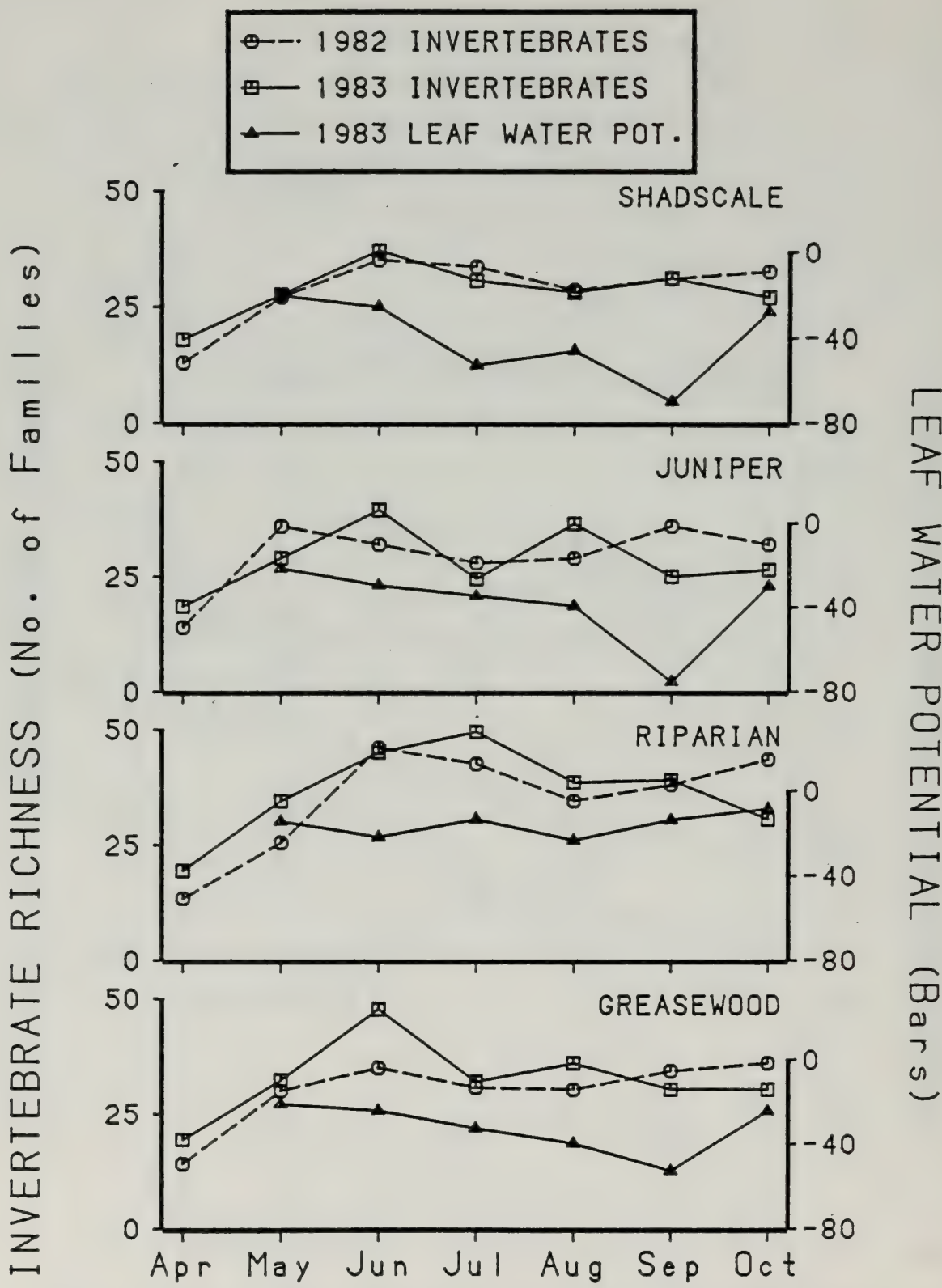

Figure 5.4-13 Richness (number of families) of all invertebrates on big sagebrush in four vegetation types in 1982 and 1983 and leaf water potential (bars) of big sagebrush in four vegetation types in 1983.

As with host plants, correlations (r) between abundance (expressed as ind/m^3) and mean leaf water potential were weak, being 0.06 for vegetation types and 0.00 for transects (Table 5.4-14). These correlations were also weak for biomass (mg/m^3). However, these relationships were much stronger using the other indices. In addition, correlations between water potential and richness and diversity were quite strong, being 0.95 and -0.76, respectively, for vegtypes and 0.86 and -0.46, respectively, for transects (Table 5.4-14). The major functional groups all showed a strong correlation of biomass (mg/m^2) with mean leaf water potential of the four vegetation types (r=0.63 to 0.99; Table 5.4-15).

August grasshopper densities (ind/ha) were estimated at 34000 in WG-1, 14000 in WR-2, 12000 in WS-1, and 2000 in WJ-1. These densities are not very high. Onsager (1983), for instance, has commonly expected grasshopper densities above the USDA/APHIS "action threshold" of 8.75/m^2 (=87500/ha) for regions in Montana.

5.4.4 Reptiles

During 1983 ten species of reptile occurred at Ua-Ub. The abundances of eastern fence lizards (Sceloporus undulatus) and tree lizards (Urosaurus ornatus), in wooded vegetation types increased above their upper 95% confidence limit established during the baseline period. The abundance of sagebrush lizards (Sceloporus gracious), side-blotched lizards (Uta stansburiana), and western whiptail lizards (Cnemidophorus tigris) in the shrub and some wooded vegetation types dropped below their lower 95% confidence limits.

Table 5.4-15 Mean biomass ($mg/^2$) of the most important invertebrate functional groups on big sagebrush in four vegetation types from May to October, 1983. Correlations (r) between leaf water potential (see Table 5.4-14) and biomass are shown at right.

	Vegetation Type				
Group	Greasewood	Juniper	Shadscale	Riparian	r
Sap-feeders	32.32	16.04	10.21	29.30	0.63
Leaf-chewers	21.06	14.02	9.92	35.52	0.97*
Saprophores	0.37	0.36	0.43	1.01	0.96*
Predators	6.99	4.93	7.57	14.75	0.95*
Parasites	0.41	0.15	0.17	0.48	0.82
Various Diptera	0.39	0.38	0.25	1.56	0.99*

*$p<0.05$.

These changes may be linked to annual plant productivity. The abundant annual-plant growth in 1983 may have interfered with or concealed the latter three species which are all ground dwelling forms. The former two species are primarily arboreal lizards and were not so affected.

Two snakes, the gopher snake (Pituophis melanoleucus) and midget-faded rattlesnake (Crotalus viridis concolor), had high abundances in xeric upland vegetation compared to the baseline period. The racer (Coluber constrictor) had medium abundance in Riparian, and the striped whipsnake (Masticophis taeniatus) was encountered infrequently. The increase in gopher snakes and rattlesnakes is likely due to an increase in their main food resources (rodents, bird's eggs, and invertebrates).

Reptilian abundance, richness, and diversity changed appreciably at one Greasewood site but remained within or near their 95% confidence limits at the other two sites (Figure 5.4-14). The decline in abundance and richness is attributed to the extensive cheatgrass cover at site WG-1 that may have limited activity to a few open areas and sparsely vegetated washes.

Reptiles in Juniper (Figure 5.4-15), Shadscale (Figure 5.4-16), and Riparian (Figure 5.4-17) showed no development-related changes. Species diversity in WJ-1 was above its established 95% confidence interval. In Riparian, population parameters for WR-4 fell within the limits established at WR-1, both below WR-2. Low abundance, richness, and diversity at WR-1 and WR-4 are attributed to a lack of bare ground and salt-tolerant shrubs that are more predominant at WR-2. Their predominance at WR-2 is due to saline alluvial soils deposited by flash floods and saline colluvial soils deposited

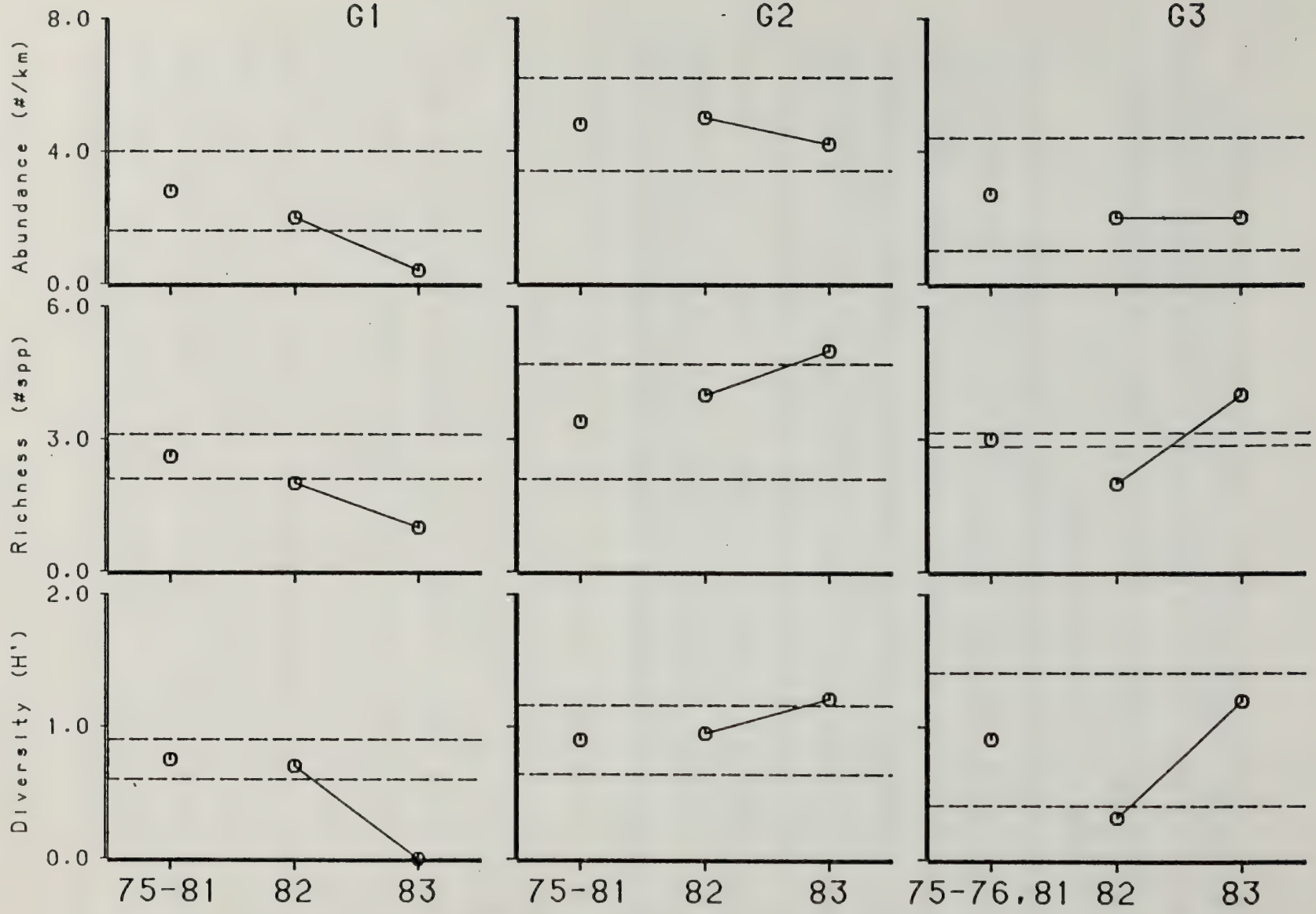

Figure 5.4-14 Abundance (ind/km) and diversity (H') of reptiles in Greasewood in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

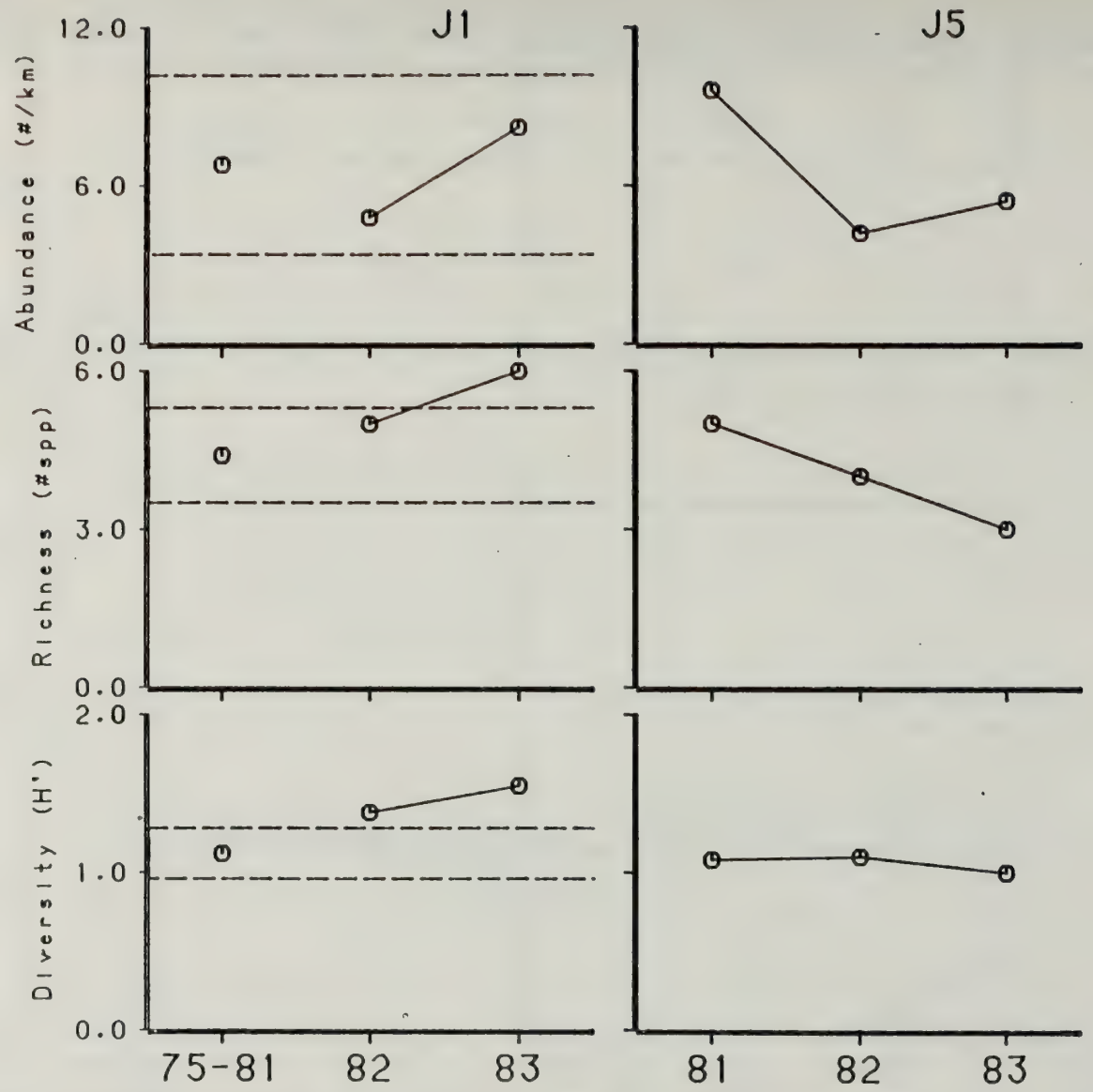

Figure 5.4-15 Abundance (ind/km) and diversity (H') of reptiles in Juniper in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

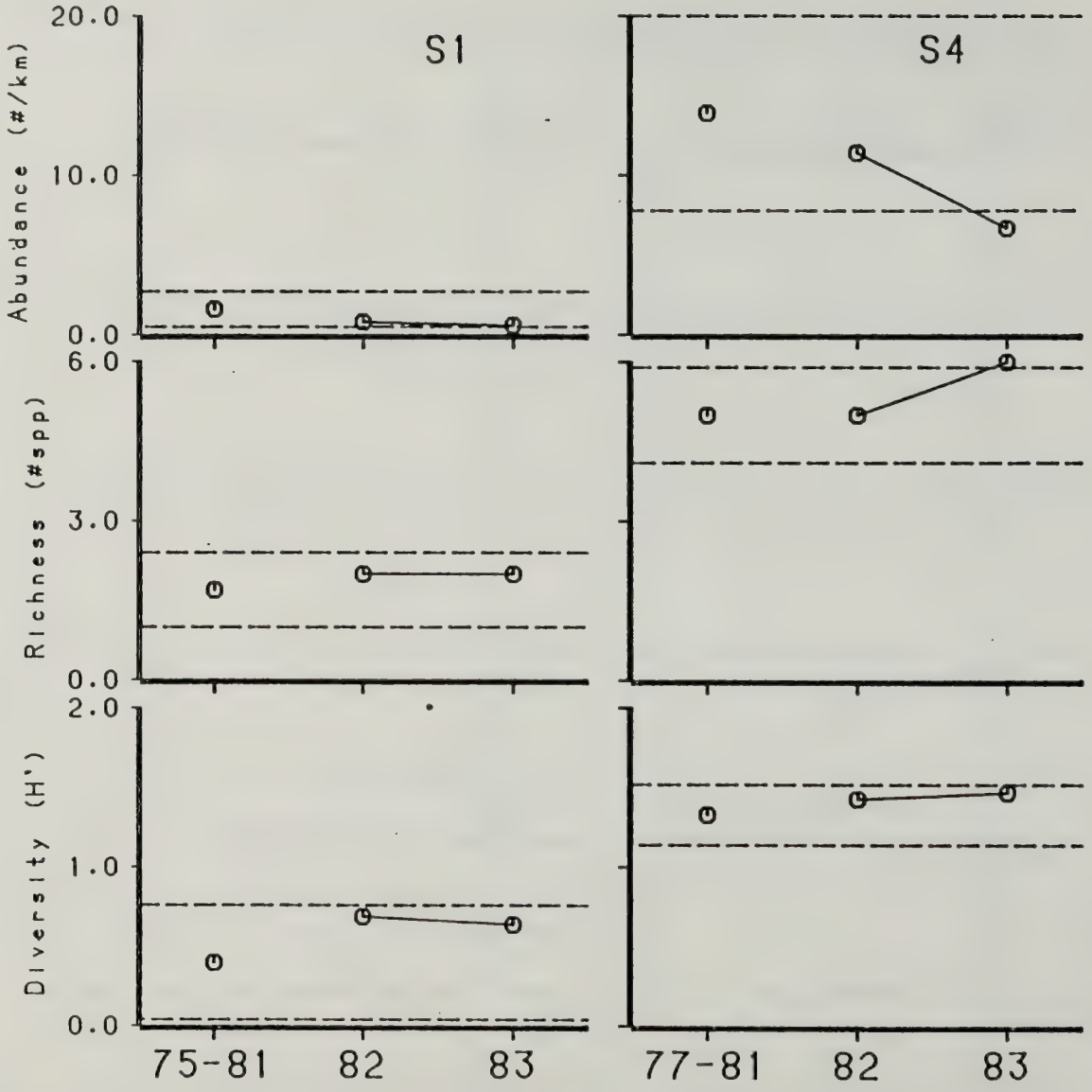

Figure 5.4-16 Abundance (ind/km) and diversity (H') of reptiles in Shadscale in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

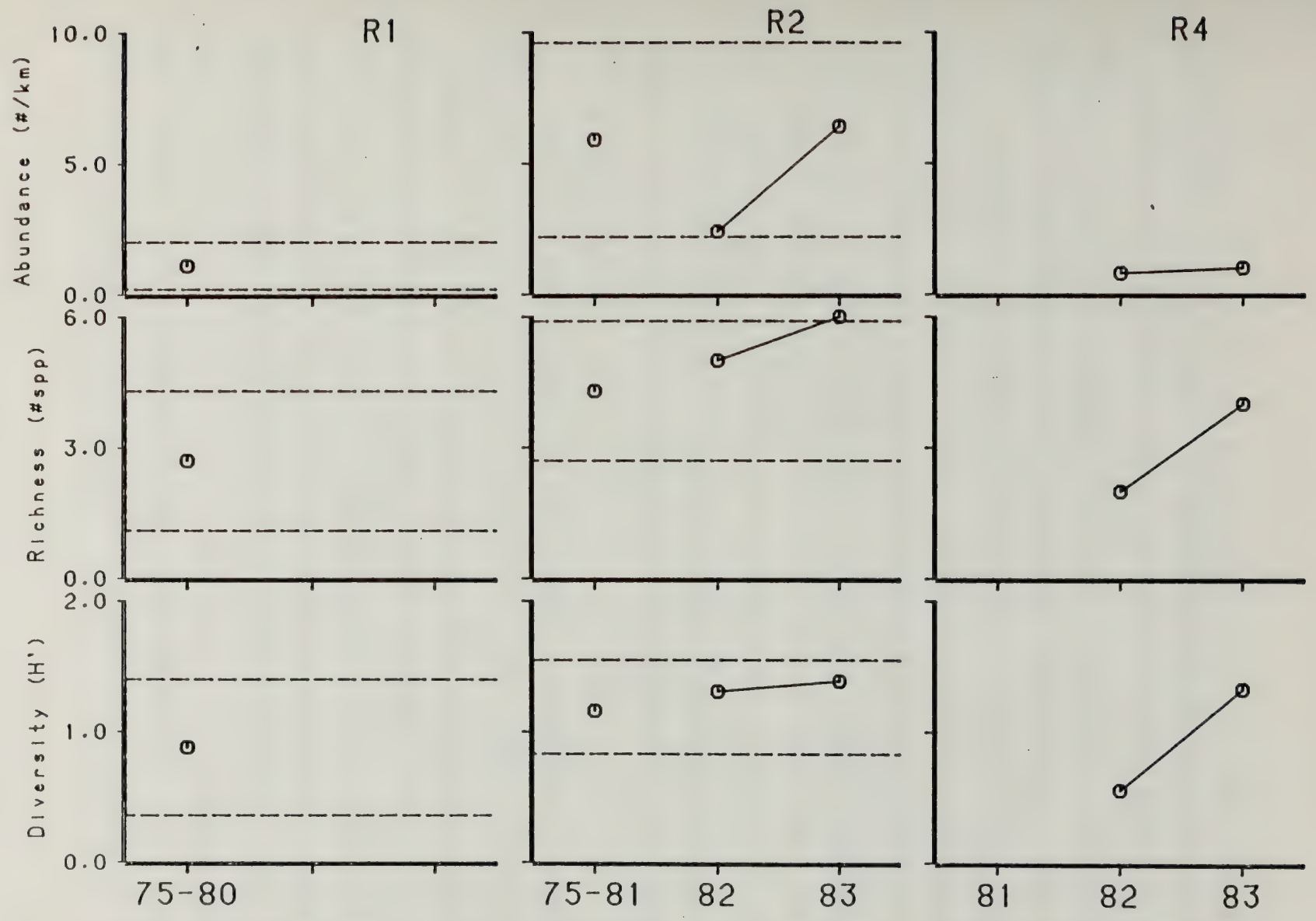

Figure 5.4-17 Abundance (ind/km) and diversity (H') of reptiles in Riparian in June 1981 and 1982, compared to means in June during the baseline period (1975-1981). 95% confidence limits of the baseline data are horizontal broken lines.

The value of graphically displaying reptilian population parameters as well as tracking individual species was vividly illustrated during 1983. Following June's sampling session, the conclusion was reached that development at the plant site may have affected the reptiles at sampling site WJ-5. The supposed impact resulted in the absence of sagebrush lizards (formerly a common species in Juniper) and whiptail lizards. However, both species were at low abundance throughout Ua-Ub as explained above and had been below the established confidence interval since 1982 suggesting that the decline may have had other causes. To verify this conclusion, WJ-5 was sampled again in August. Both species were present with abundance in a normal range for WJ-5.

Similarity indices were used in 1983 to test the degree of similarity between control treatment pairs of sampling sites. Differences in similarity indices for reptilian abundance among sixteen site pairs were tested by one-way ANOVA. The similarity index for the WJ-1/WJ-5 pair, which exceeded indices for all other pairs ($p<0.05$), averaged 72 ± 4 percent over three years. The lowest percent similarity was for the WS-1/WS-4 pair (13 ± 5). Interestingly, WJ-1 and WJ-5 are more similar to WS-4 ($66\pm3\%$ and $60\pm7\%$, respectively) than the Shadscale sites are to each other. Greasewood pairs were at median similarity and Riparian pairs were not comparable for a three-year period. Similarity indices for species composition were much more variable but showed a similar pattern.

The high similarities between WS-4 and the Juniper sites are probably due more to physical factors than to biological factors. Sandstone outcrops and

shallow soils derived from the Unitah Formation at sites WJ-1, WJ-5, and WS-4, appear to be important, outweighing the influence of vegetation structure and productivity which are quite different at WS-1. In addition, the proximity of vegetation types may be important. Site WS-4 is adjacent to the Juniper vegetation and has some scattered juniper trees located along its sampling area. The types of soils, their depth, and the occurrence of sandstone outcropping seem to play a major role in lizard abundance. The analysis suggests, at least for reptiles, that habitat preference though usually based on vegetative characters must also consider physical factors, namely soils, land forms, and topography.

5.4.5 Birds

Results of monitoring bird communities are divided into five sections: spring birds, summer (breeding) birds, aquatic birds, raptors, and threatened and endangered species.

5.4.5.1 Spring Bird Community As in 1982, the spring bird community was dominated by ground foragers (Table 5.4-16). However, there were several differences in the 1982 and 1983 bird communities. In Greasewood, consuming biomass decreased sharply, but granivores and ground insectivores both increased. In Juniper, omnivores again decreased sharply while granivores and ground insectivores decreased slightly. Ground insectivores decreased on Shadscale, and in Riparian granivores decreased to nearly one-half of the consuming biomass in 1982 while both ground insectivores and omnivores more than doubled. As in the baseline period, trunk and foliage insectivores were scarce in all habitats during April.

Table 5.4-16 Consuming biomass (g/20 ha) of avian foraging guilds in April 1983 on the Utah Shale Oil Tracts, Ua and Ub.

Trophic Group*	Guild†	Vegetation Types			
		Greasewood	Juniper	Shadscale	Riparian
G	GGG	237.7	63.0	76.7	396.7
O	GGO	5.3	77.4	0.0	152.0
I		139.8	32.8	67.9	379.8
	ACI	0.0	0.0	5.6	1.4
	AHI	0.7	2.0	3.2	0.0
	BGI	2.0	0.0	0.0	0.0
	BPI	0.0	0.0	0.0	28.4
	FGI	3.5	2.2	0.0	12.2
	GGI	133.6	28.6	59.1	337.8
R	R	3.2	0.0	3.2	0.0
TOTAL		386.0	173.2	147.8	928.5

*G = Granivore; O = Omnivore; I = Insectivore.
†GGG = Ground-gleaning Granivore; GGO = Ground-gleaning Omnivore; ACI = Air-cruising Insectivore; AHI = Air-hawking Insectivore; BGI = Bark-gleaning Insectivore; BPI = Bark-probing Insectivore; FGI = Foliage-gleaning Insectivore;. GGI = Ground-gleaning Insectivore; N = Nectarivore; R = Raptor (exclusing hawks and owls).

The most common species were: pinyon jays (Gymnorhinus cyanocephalus), 4.1 ind/20 ha in Juniper; mountain bluebirds (Sialis currucoides), 13.1 ind/20 ha in Greasewood; house finchs (Carpodacus mexicanus), 35.6 ind/20 ha in Riparian; and dark-eyed juncos (Junco hyemalis), 34.8 ind/20 ha in Greasewood, 24.7 ind/20 ha in Riparian, and 8.2 ind/20 ha in Juniper.

5.4.5.2 Breeding Bird Community Seventy-six bird species were seen on the study tracts in June. Species composition was similar to that recorded in 1982 (WRSOC Progress Report, 1983, Table 5.4-13) with a few exceptions. Two Northern Mockingbirds (Mimus polyglottos), a southern species observed in only three of the last eight years, were recorded in June. One was in the greasewood habitat near the mouth of Asphalt Wash and the other at WR-2. During the April waterfowl survey, ring-necked ducks (Aythya collaris) were recorded for the first time. This species is an uncommon spring migrant through Utah and probably occurs on the tracts occasionally in low numbers. In August, a sage grouse (Centrocercus urophasianus) was sighted on Tract Ub at the junction of the new highway and the road to Asphalt Wash. This is the first sighting of the sage grouse on or near the study tracts.

The breeding bird community in the shrub habitats (Greasewood and Shadscale) were dominated by granivores (Table 5.4-17). In the forested habitats (Juniper and Riparian), the dominant trophic groups were omnivores and insectivores, respectively.

Table 5.4-17 Consuming biomass (g/20 ha) of avian foraging guilds in June 1983 at the Utah Shale Oil Tracts, Ua and Ub.

Trophic Group*	Guild*	Vegetation Types			
		Greasewood	Juniper	Shadscale	Riparian
G	GGG	198.6	59.6	126.0	300.8
O	GGO	61.9	196.2	0.0	361.8
I		65.5	129.3	89.1	3,427.5
	ACI	10.9	14.8	14.3	1,539.9
	AHI	5.2	41.3	5.2	221.4
	BGI	0.0	7.0	0.0	26.2
	BPI	0.0	0.0	0.0	34.3
	FGI	9.4	47.2	0.0	1,075.7
	GGI	40.0	19.0	69.6	530.0
N	N	0.0	0.0	0.0	7.7
R	R	0.9	2.5	0.0	0.0
TOTAL		326.9	387.6	215.1	4,097.8

*See Table 5.4-16 for symbol definitions.

Consuming biomass of the breeding bird communities [excluding raptor, aquatic birds, and air-cruising insectivores (swifts and swallows)] in all habitats increased between 1982 and 1983 (Figure 5.4-18). In Riparian habitat, this increase exceeds the 95% confidence limits for the seven-year baseline period (Figure 5.4-19). This dramatic increase in Riparian is due primarily to insectivorous species that, as a trophic group, also exceeded the 95% confidence limit (Figure 5.4-19). Granivores and omnivores on the same site both showed moderate declines in consuming biomass. The increase in insectivores in Riparian was broadly based, occurring in all major guilds: ground-gleaners, air hawkers, and bark probers. Even the air-cruising insectivores (which were excluded from this comparison because they are highly variable and difficult to census due to their constant movement) showed a marked increase between 1982 and 1983.

In the other three habitats, major trophic groups (insectivores, granivores, and omnivores) generally increased, although only omnivores in Juniper exceeded the 95% confidence limits (Figure 5.4-20). Insectivores in Greasewood (Figure 5.4-21) granivores in Juniper (Figure 5.4-20) fell slightly below the lower 95% confidence limit. Among the major insectivorous guilds, ground-gleaners had low consuming biomass in 1983 (Figures 5.4-20 and 5.4-21) whereas air-hawkers had high consuming biomass (Figures 5.4-19, 5.4-20, and 5.4-22). Changes in consuming biomass of trophic groups and guilds from 1975 through 1981 are shown in Figures 5.4-23 through 5.4-26).

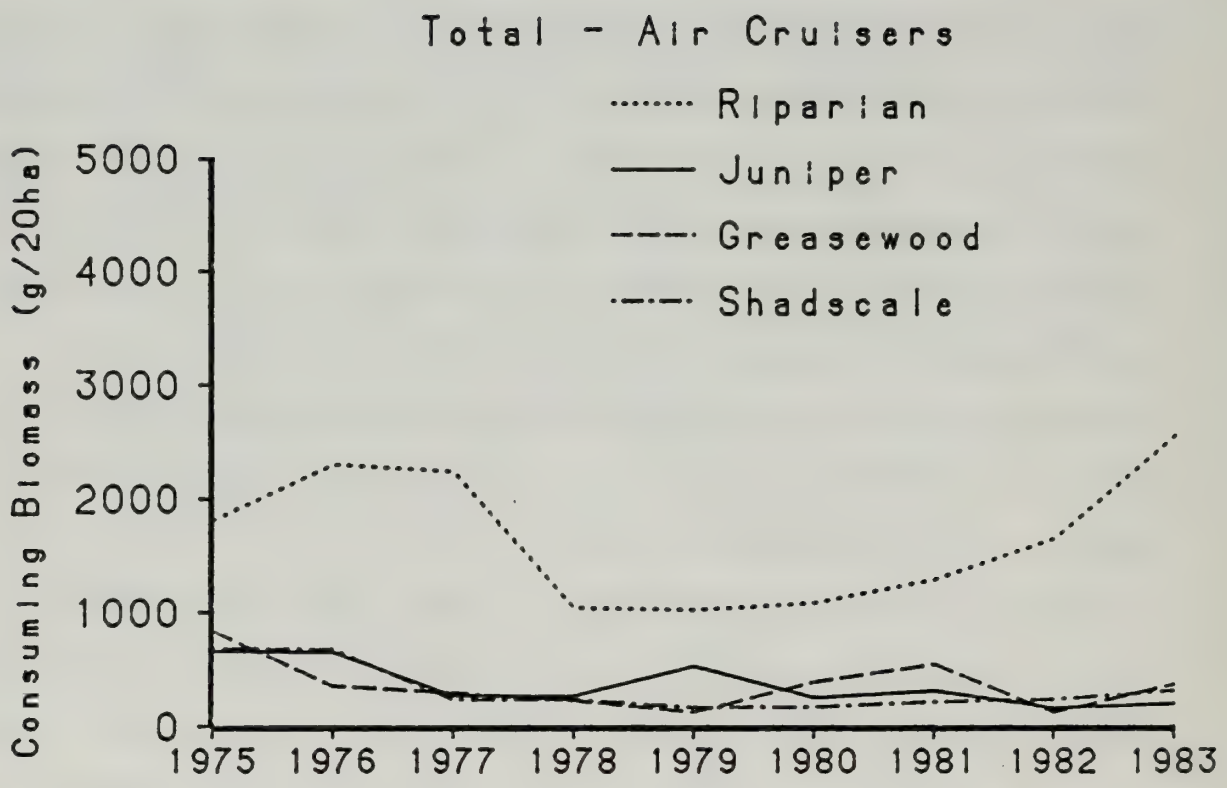

Figure 5.4-18 Consuming biomass (g/20 ha) of the bird community in June from 1975 through 1983 in four habitats.

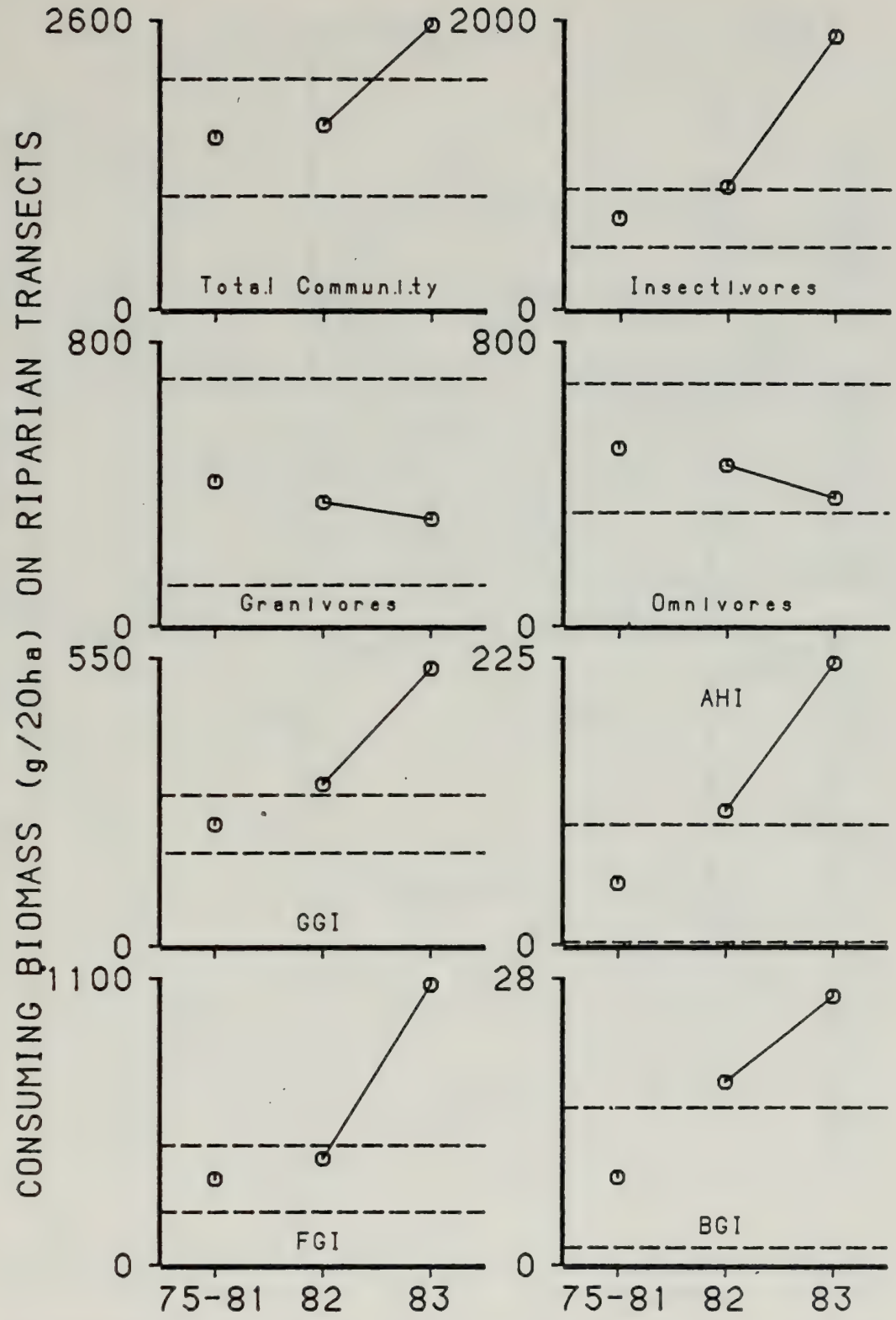

Figure 5.4-19 Consuming biomass (g/20 ha) of the bird community, trophic groups, and select insectivore guilds in Riparian in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations defined in Table 5.4-16.

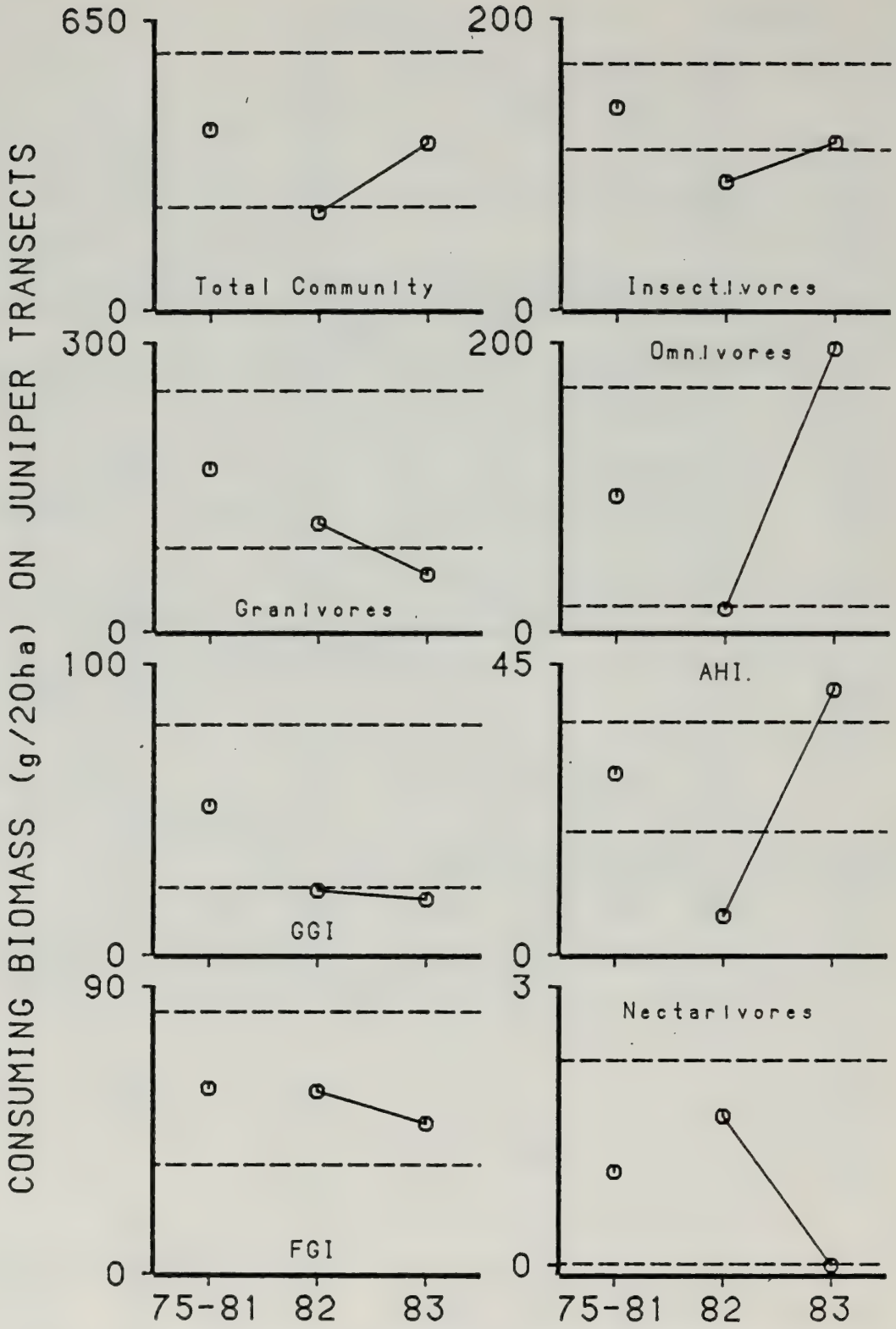

Figure 5.4-20 Consuming biomass (g/20 ha) of the bird community, trophic groups, and select insectivore guilds in Juniper in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations defined in Table 5.4-16.

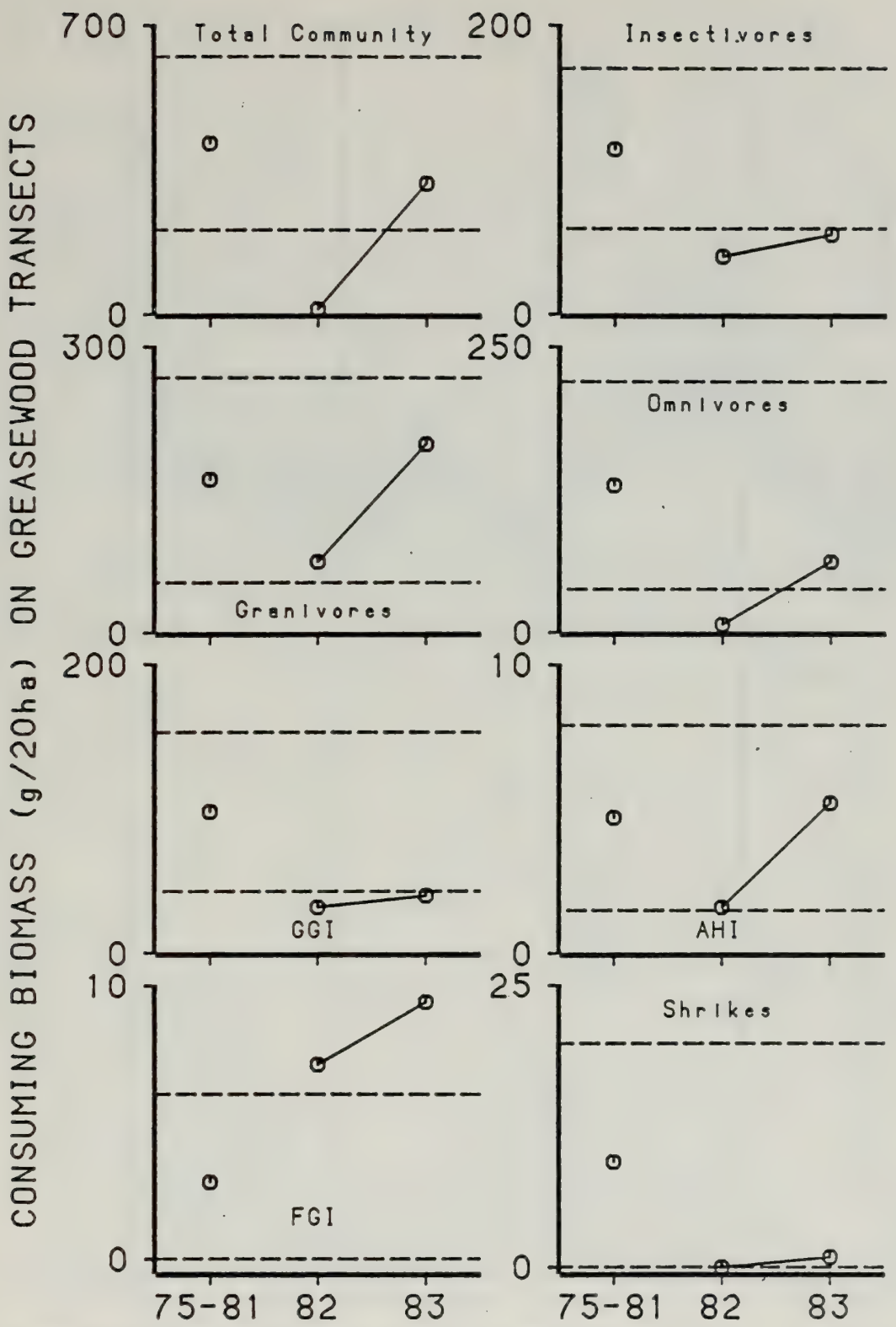

Figure 5.4-21 Consuming biomass (g/20 ha) of the bird community, trophic groups, and select insectivore guilds in Greasewood in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations defined in Table 5.4-16.

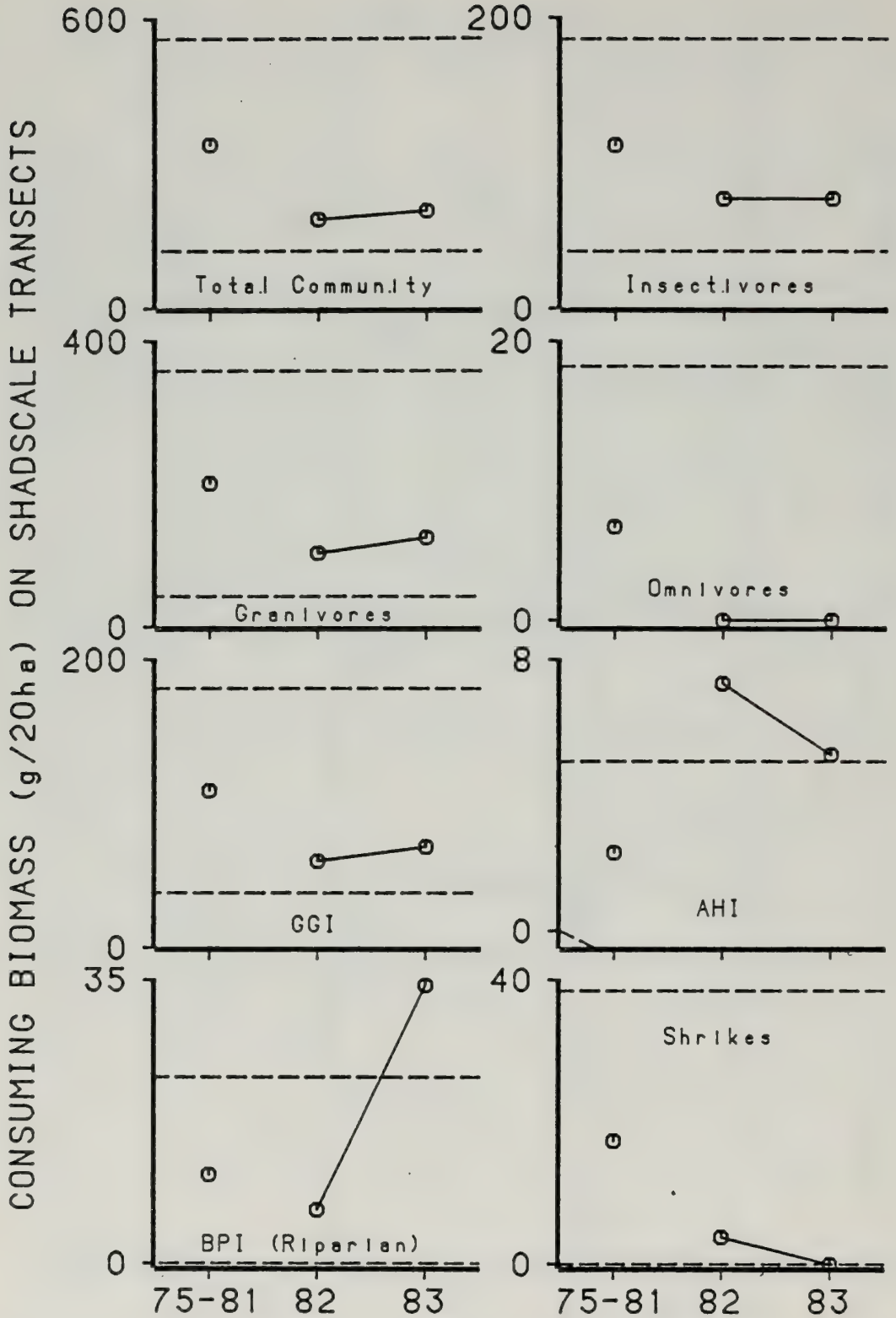

Figure 5.4-22 Consuming biomass (g/20 ha) of the bird community, trophic groups, and select insectivore guilds in Shadscale in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations defined in Table 5.4-16.

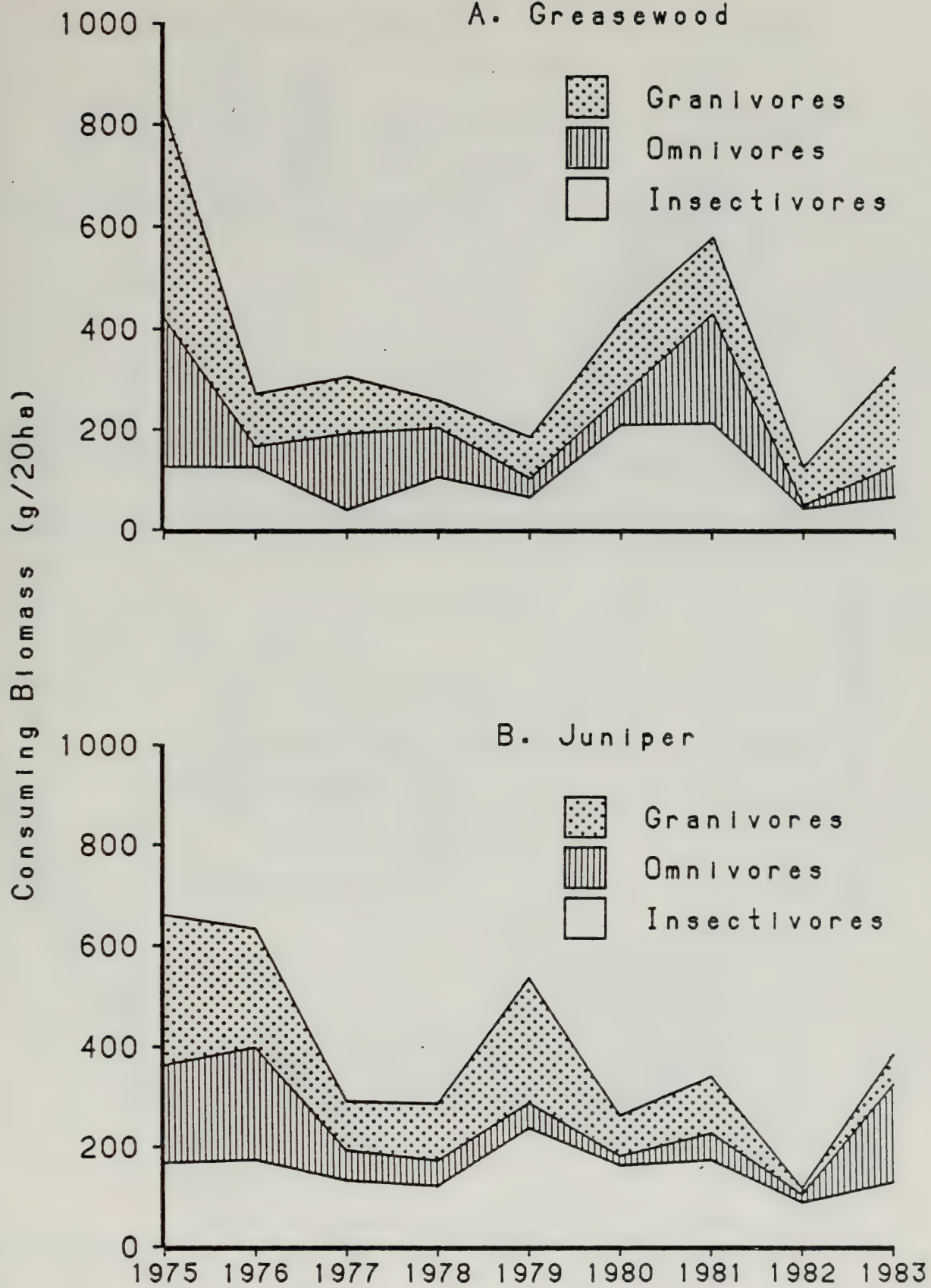

Figure 5.4-23 Consuming biomass (g/20 ha) of three avian trophic groups in June from 1975 through 1983 in Greasewood and Juniper.

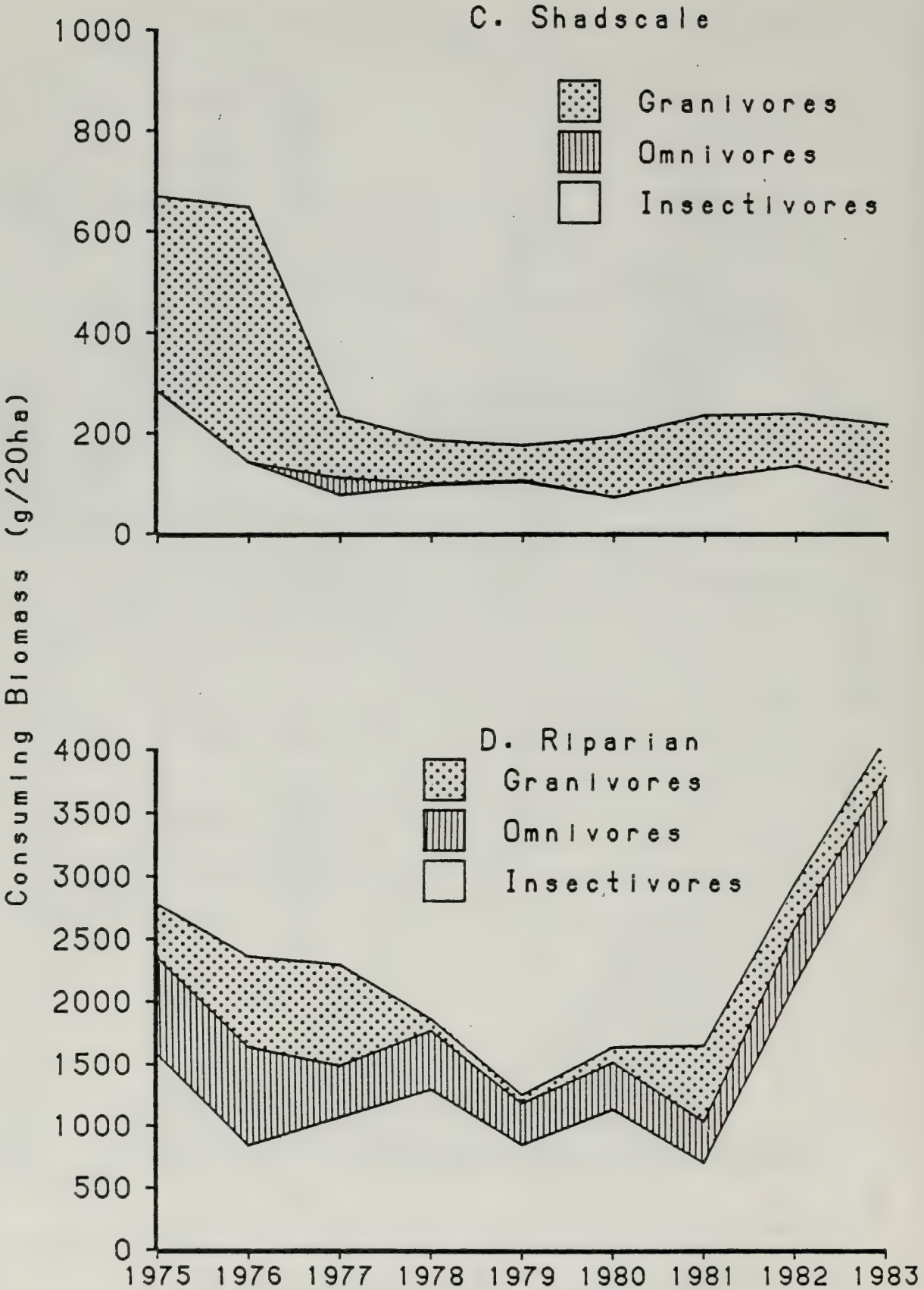

Figure 5.4-24 Consuming biomass (g/20 ha) of three avian trophic groups in June from 1975 through 1983 in Shadscale and Riparian.

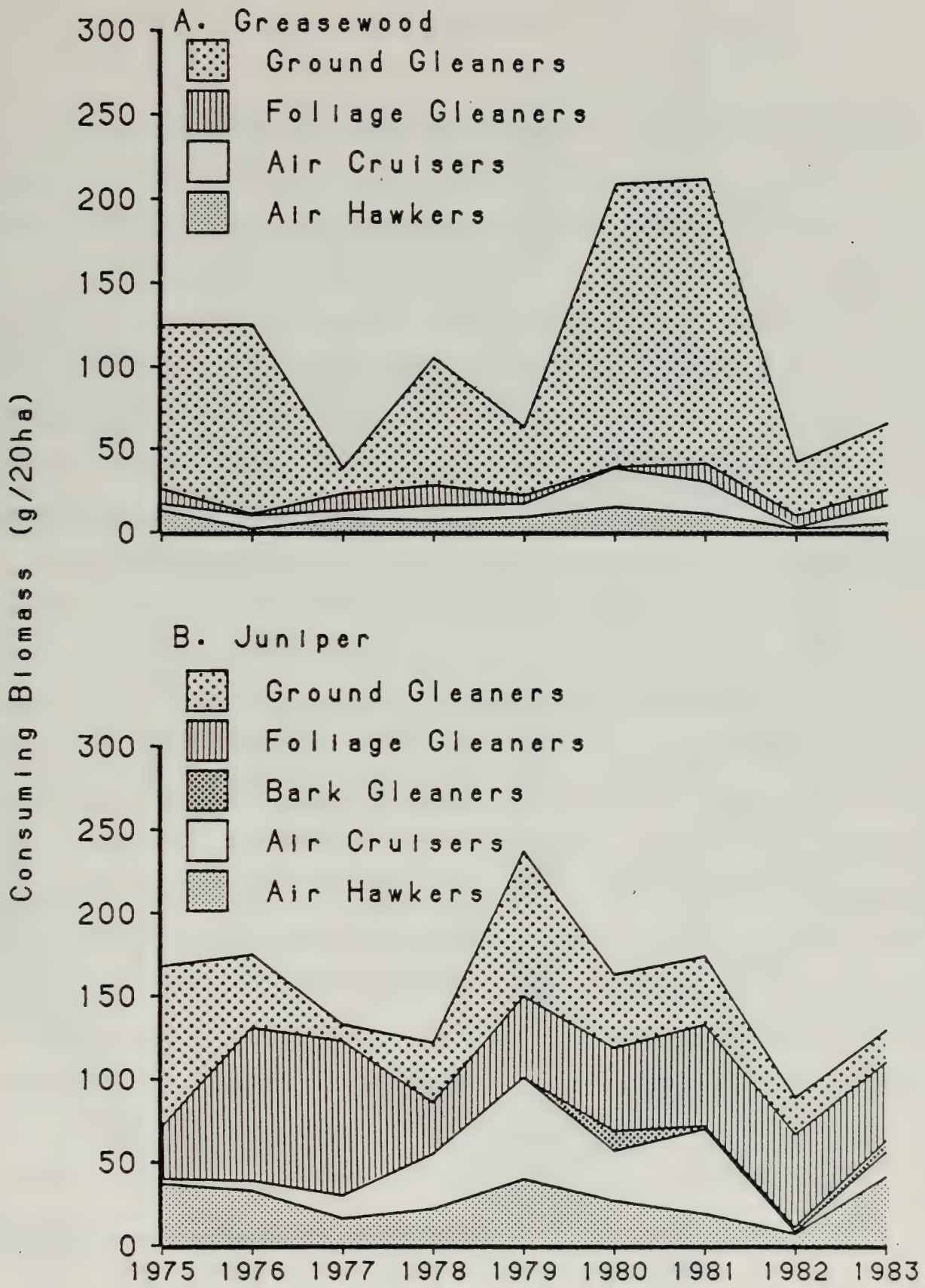

Figure 5.4-25 Consuming biomass (g/20 ha) of insectivore guilds in June from 1975 through 1983 in Greasewood and Juniper.

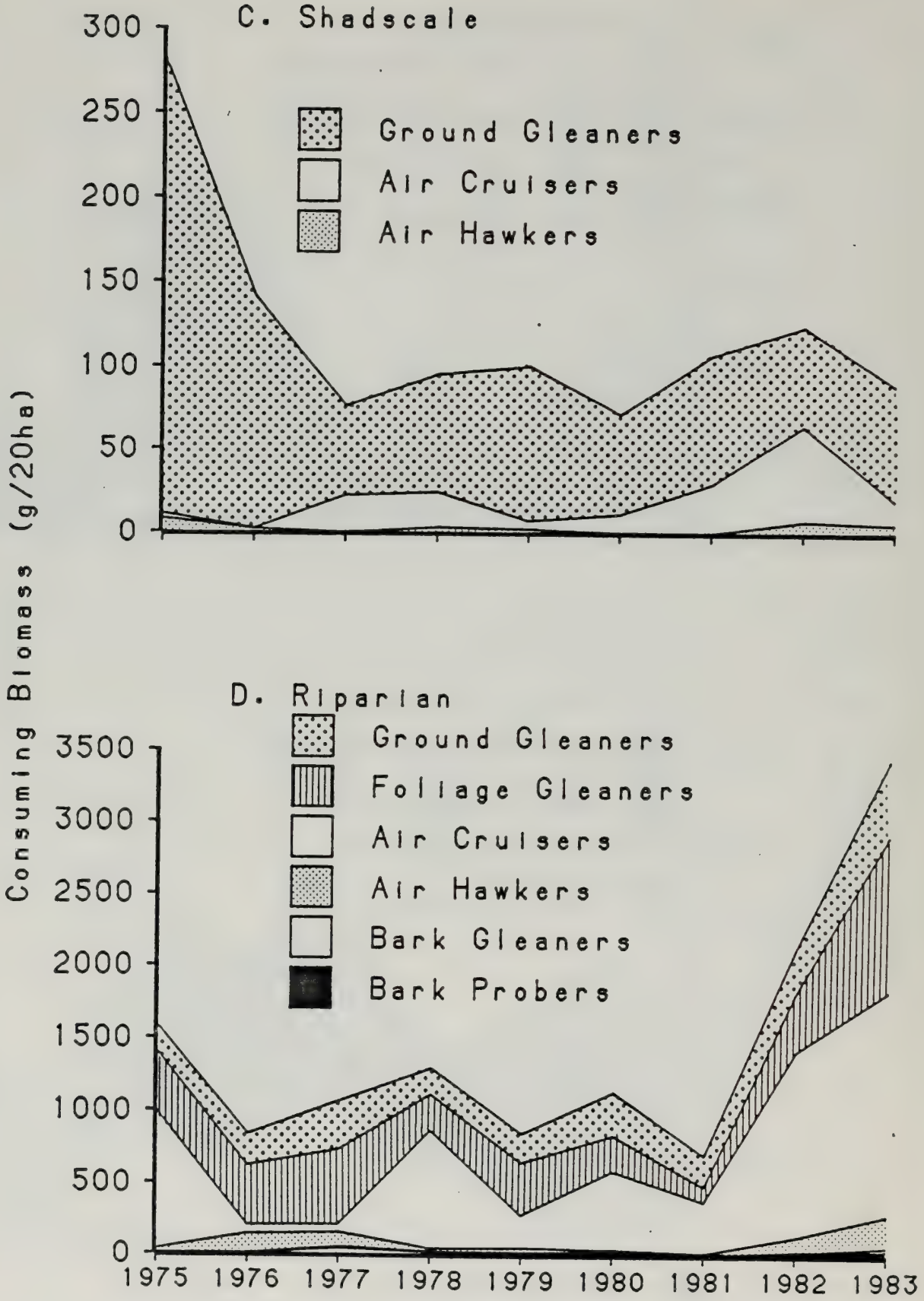

Figure 5.4-26 Consuming biomass (g/20 ha) of insectivore guilds in June from 1975 through 1983 in Shadscale and Riparian.

Bird species richness increased between 1982 and 1983 on all sites except Shadscale (Figure 5.4-27). The most marked increase occurred in Juniper (Figure 5.4-28) with smaller increases in Greasewood (Figure 5.4-29) and Riparian (Figure 5.4-30). These increases were due to an increase in insectivores. In Greasewood and Juniper, these increases were due primarily to increases in foliage-gleaners, whereas in Riparian ground-gleaners and air-cruisers made the largest contribution. Patterns in density and species diversity generally paralleled those described for consuming biomass and species richness, respectively.

5.4.5.3 Waterfowl Survey A waterfowl survey was conducted by canoe along a 33 km stretch of the White River from Cowboy Canyon to Asphalt Wash. Surveys were made on three consecutive days starting on 14 April. Waterfowl abundance and species richness on the first two days of the survey were low, apparently due to inclement weather, but by the third day the weather cleared and waterfowl abundance increased. Six species of waterfowl were recorded in 1983 compared to 11 species in 1982 (Table 5.4-18). The Canada goose (Branta canadensis), green-winged teal (Anas crecca), and mallard (Anas platyrhychos) were the most common species in 1982. Each of these species was slightly less common in 1983 than in 1982. Ring-necked ducks (Aythya collaris) were recorded for the first time, but six uncommon species recorded in 1982 were not seen in 1983. Decreased waterfowl abundance and species richness in 1983 were probably due primarily to inclement weather just prior to the sampling session.

Table 5.4-18 Waterfowl abundance (individuals/river km) along the White River from Cowboy Canyon to Asphalt Wash, 7-9 April 1982 and 14-16 April 1983.

Species	Cowboy Canyon to Dam Site (km 0-24.1		Dam Site to Asphalt Wash (km 24.1-32.8)		Total Survey	
	1982	1983	1982	1983	1982	1983
Canada Goose	1.88	1.86	1.23	0.34	1.71	1.46
Green-winged Teal	0.52	0.37	0.58	0.35	0.54	0.37
Mallard	0.36	0.25	0.42	0.29	0.38	0.25
Gadwall	0.19	0.19	0.00	0.04	0.14	0.15
American Wigeon	0.10	0.00	0.00	0.00	0.07	0.00
Lesser Scaup	0.08	0.00	0.04	0.00	0.07	0.00
Northern Shoveler	0.00	0.00	0.23	0.00	0.06	0.00
Blue-winged Teal	0.00	0.07	0.19	0.00	0.05	0.05
Red-breasted Merganser	0.07	0.00	0.00	0.00	0.05	0.00
Common Merganser	0.04	0.00	0.00	0.00	0.03	0.00
Ring-necked Duck	0.00	0.04	0.00	0.00	0.00	0.03
Cinnamon Teal	0.00	0.00	0.11	0.00	0.03	0.00
All Waterfowl	3.24	2.78	2.80	1.02	3.13	2.31

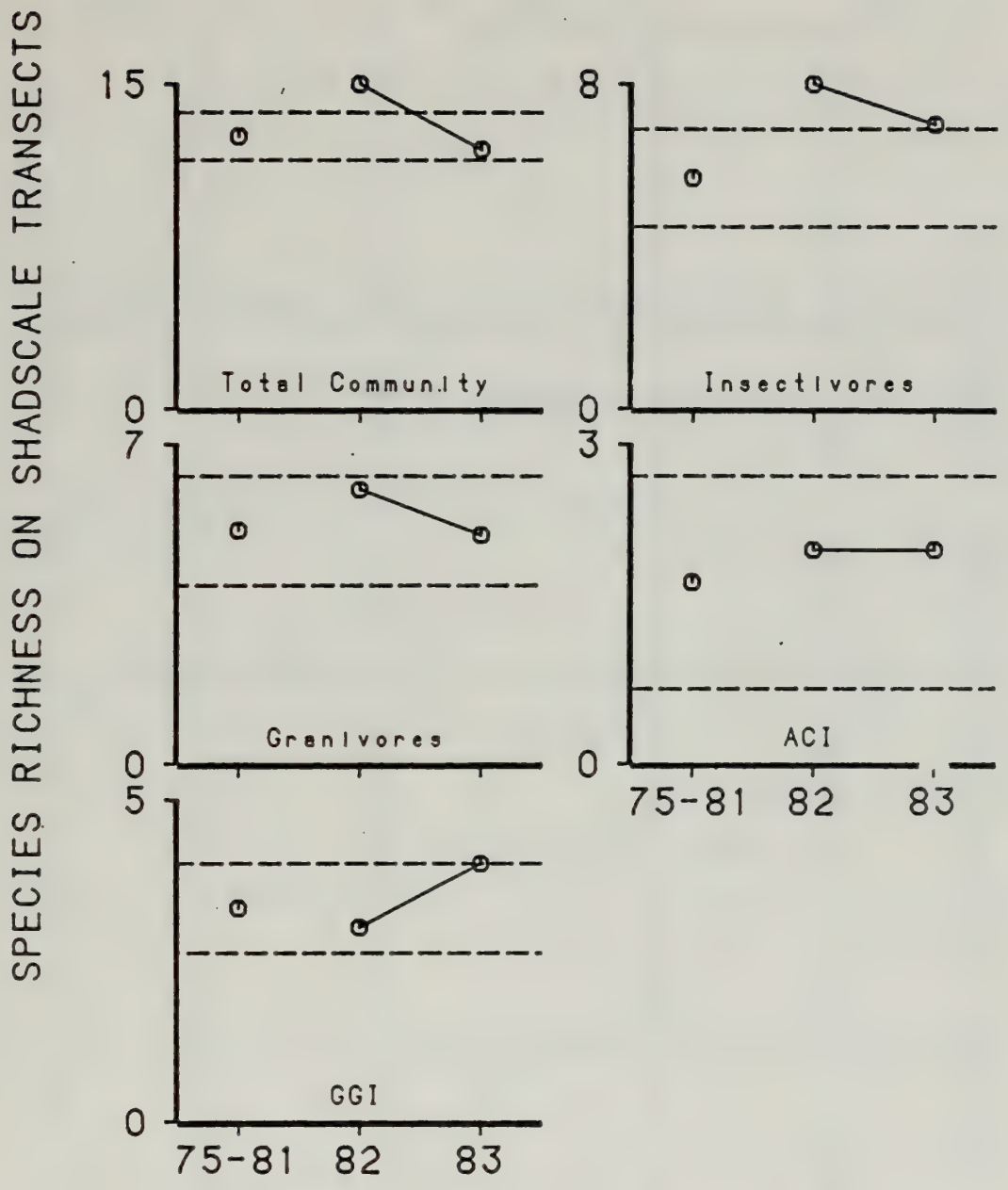

Figure 5.4-27 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivore guilds in Shadscale in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-16.

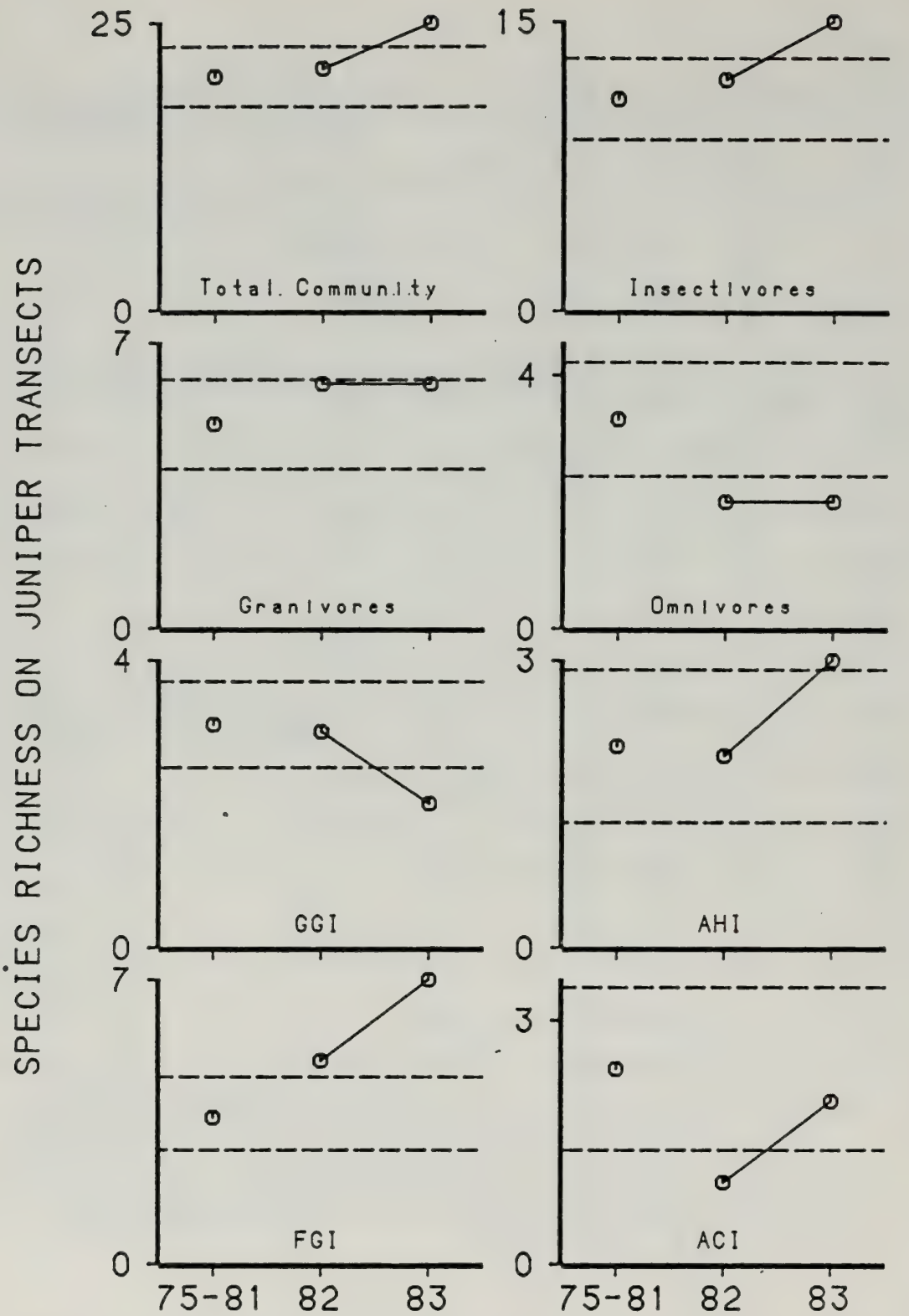

Figure 5.4-28 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivore guilds in Juniper in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-16.

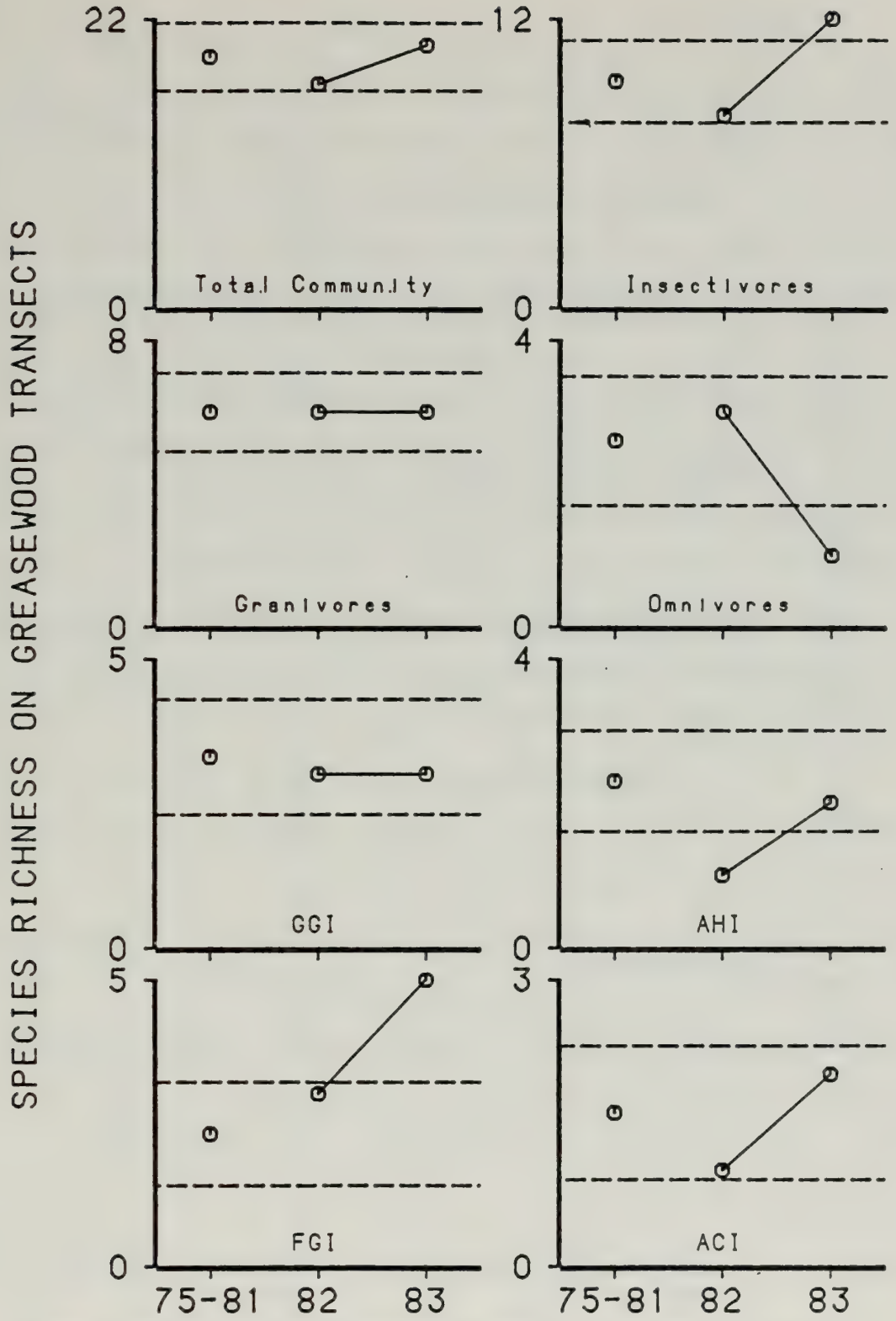

Figure 5.4-29 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivore guilds in Greasewood in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-16.

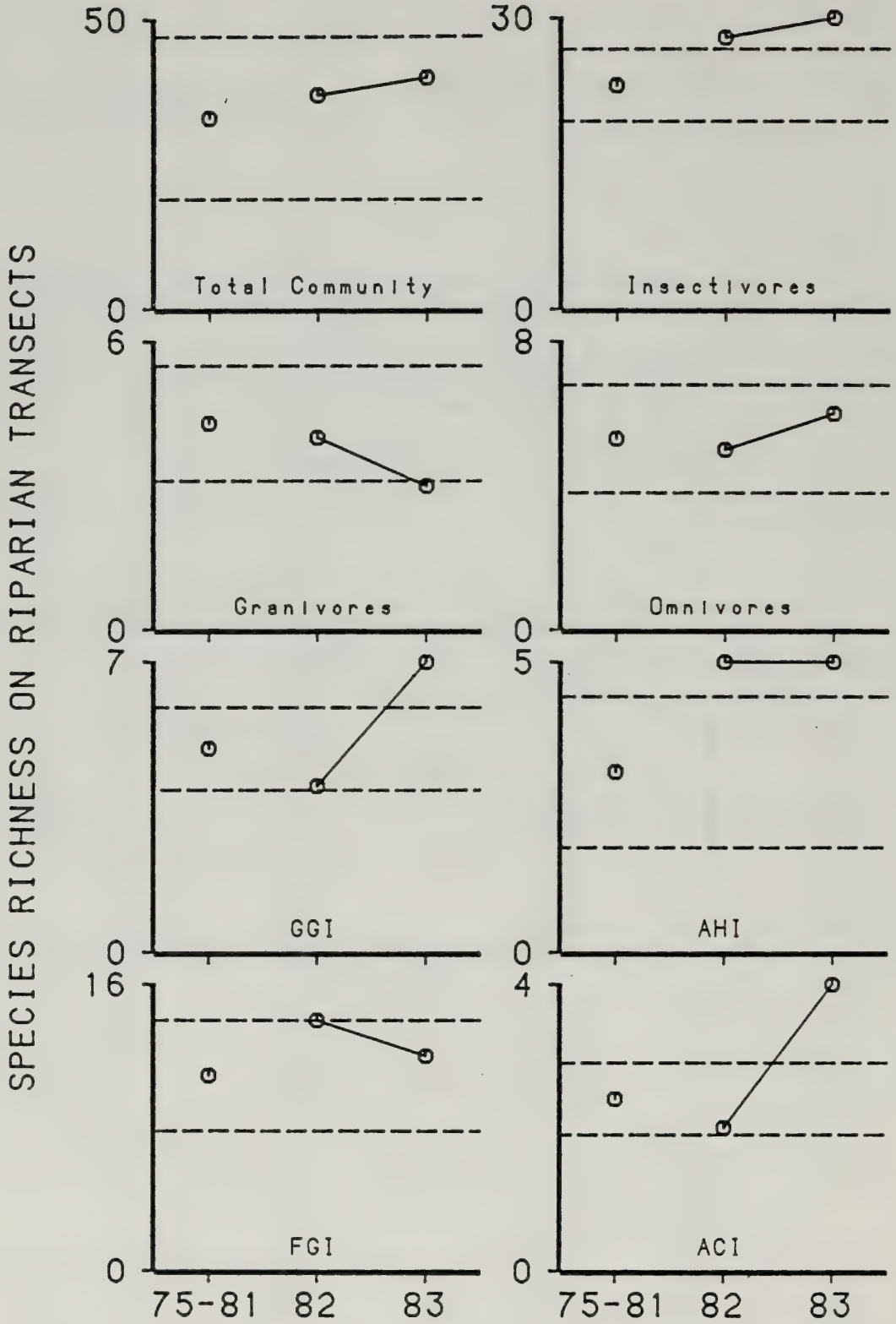

Figure 5.4-30 Species richness (number of species recorded) for the avian community, trophic groups, and select insectivore guilds in Riparian in June 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981). Guild abbreviations are defined in Table 5.4-16.

5.4.5.4 Raptors The raptor nest survey conducted in February, April, June, and September, 1983, covered most of the 58 nests located in the 1982 survey, plus several areas that were not covered in detail in 1982. An additional 38 nests were located, and seven "nests" were dropped from the list (these are probably roosts, not nests) raising the total number of nests on or within two miles of Tracts Ua and Ub to 90.

The discovery that golden eagles (Aquila chrysaetos) used a nest (nest 15) in 1983 that was used by red-tailed hawks (Buteo jamaicensis) in 1982 and the presence of a red-tailed hawk in a large nest (nest 6) probably built by eagles has led us to describe stick nests as large or small rather than assigning them to a particular species. Any nest described as "large" could potentially be used either by eagles, red-tailed hawks, or by ravens (Corvus corax) whereas those labeled as "small" would be restricted to red-tailed hawks or ravens unless extensive nest rebuilding occurs.

Twenty active nests iwere located in 1983 on or near the tracts (Table 5.4-19). Golden eagles (7 nests) and red-tailed hawks (7 nests) were the most common breeders. The nests of one pair of Cooper's hawks (Accipter cooperii), one pair of prairie falcons (Falco mexicanus), three pairs of great horned owls (Bubo virginianus) and one pair of long-eared owls (Asio otus) were also located. In addition, it is suspected that another pair of long-eared owls bred in Asphalt Wash near nest 46, that one pair of prairie falcons nested near nest 56, and that one or more pairs of northern harrier (Circus cyaneus) nested along the flood plan of the White River to the north of the tracts.

Table 5.4-19 Number of active raptor nests in the vicinity of the Utah Oil Shale Tracts, Ua and Ub, in 1982 and 1983.

Species	1982	1983
Golden Eagle	3	7
Red-tailed Hawk	3	7
Cooper's Hawk	1	1
Prairie Falcon	1	1
Great Horned Owl	3	3
Long-eared Owl	1	1
Raven	0	0
TOTAL	12	20

Two pairs of golden eagles, four pairs of red-tailed hawks, and one pair of great horned owls nested within the boudaries of Tracts Ua and Ub. The closest active nests to the plant site were nest 35, a golden eagle nest about one kilometer northwest of construction sites but located on the northwest face of a small butte facing away from the plant site, and nest 69, a red-tailed hawk nest two kilometers northeast of the plant site. Both nests appear to be unaffected by construction activity or highway traffic.

None of the three golden eagle nests used in 1982 was used in 1983, and only one (nest 41) of three red-tailed hawk nests used in 1982 was used in 1983. Nest 15 was used by red-tailed hawks in 1982 and golden eagles in 1983. Data in future years will indicate whether this high rate of nest switching is characteristic. At this time, however, it appears as though nest site tenacity of golden eagles and red-tailed hawks is low even if previous breeding attempts were successful. Table 5.4-20 summarizes the number of usable nests of each type that are potentially available to nesting raptors. There are 34 large stick nests and 24 small stick nests that are in good to fair condition. Thus, on the average each pair of eagles has 4.9 potential nest sites in the area and each pair of red-tailed hawks has (if the unused eagle nests are included) 7.3 nest sites in the area at 1983 population levels.

Density of breeding raptors in 1983 (20 nests) was markedly greater than in 1982 (12 nests). This difference is due primarily to increases in golden eagle and red-tailed hawk populations. During the 1983 waterfowl survey 32 golden eagles (including 15 immatures) and 21 red-tailed hawks were counted over a three-day period or 10.7 eagles/day and 7.0 hawks/day. In 1982, 13 eagles (4.3 eagles/day) and 6 red-tailed hawks (2.0 hawks/day) were seen. Thus, both the number of active nests and sightings (on waterfowl survey) more than doubled between 1982 and 1983. As of 10 June, all active nests were successful in hatching one or more young and most of these nests had fledged or would very soon fledge young (Table 5.4-21). On the average, each eagle nest produced 1.7 young and each red-tailed hawk nest produced 2.1 young.

Table 5.4-20 Condition of 90 raptor nests located on or within two miles of Utah Oil Shale Tracts, Ua and Ub, as of June 1983. A nest in good to moderate condition can be used by a breeding pair of raptors with little or no repair. A nest in poor condition requires extensive repair before it can be a useable nest. Obsolete nests are nests that are no longer present.

Nest Type	Condition		
	Good to Fair	Poor	Obsolete
Large stick nest	34	5	
Small stick nest	24	5	2
Cooper's Hawk nest	1		
Prairie Falcon nest	5	NA*	
Great Horned Owl nest	11	NA*	
Long-eared Owl nest	2	NA*	
Turkey Vulture nest	1(?)	NA*	
TOTAL	78	10	2

*These species do not build nests so nest condition cannot be judged.

Table 5.4-21 Summary of raptor nestling productivity for 1983 on and near the Utah Oil Shale Tracts, Ua and Ub. Data from 5 June to 10 June.

Species	Nest Number	Young Produced
Golden Eagle	15	2 young near fledging
	22	2 young near fledging
	26	2 young near fledging
	35	1 (maybe 2) medium-sized young
	44	2 young near fledging
	48	2 medium-sized young
	80	1 (maybe 2) downy chicks
Red-tailed Hawk	6	2 (maybe 3) medium-sized young
	13	1 (maybe 2 or 3) downy chicks
	41	2 young near fledging
	61	3 young near fledging
	69	3 young near fledging
	71	3 young near fledging
	81	1 (maybe 2 or 3) medium-sized young
Cooper's Hawk	42	1 (maybe 2 or 3) downy chicks
Prairie Falcon	76	3 or 4 young near fledging
Great Horned Owl	20	1 (or more) young fledging
	43	3 (or more) young fledging
	87	2 medium-sized young
Long-eared Owl	90	5 young fledged

These estimates are conservative because they are based on the actual number of young seen and additional young may have been present in the nest at the time of the survey.

The high density and productivity of breeding golden eagles and red-tailed hawks may be attributed to two factors: 1) the high density of prey animals (primarily desert cottontails, Sylvilagus auduboni), and 2) cool temperatures in spring and early summer. Desert cottontails were abundant, easy prey for all medium to large sized raptors. The remains of cottontail carcasses on the rim of many golden eagle and red-tailed hawk nests indicate that they are a staple food. 1983 is the second consecutive year that cottontail abundance has been high and raptor reproduction has been very successful. Cool spring and early summer temperatures are important because they reduce the number of nestling deaths due to heat stress.

Northern harrier and American kestrel (Falco sparverius) abundances also increased between 1982 and 1983. Six harriers were seen on the river survey in April 1982 (2.0 harriers/day) and 50 in April 1983 (16.7 harriers/day). Kestrels increased from 8 (2.7 ind/day) to 25 (8.3 ind/day). Although northern harriers have not nested in the area previously, frequent observations of courtship behavior and sighting of harriers along the White River in June suggest that they may have bred in the area this year. These increases in northern harriers and American kestrels may also be related to prey availability. Montane voles (Microtus montanus), not trapped in the area prior to October 1981, appear to have colonized much of the riparian habitat. Voles were discovered on WR-4 and, surprisingly, WG-2 for the first time in

April 1983. Voles rapidly become the most numerous small mammal after they colonize an area, and, due to their diurnal foraging habitat, become the primary prey of raptors such as northern harriers and sparrow hawks.

5.4.5.5 Threatened and Endangered Species The White River was surveyed by helicopter on 23 February 1983 for bald eagles and other wintering raptors. A total of 26 bald eagles were seen compared to 10 in 1982 (Table 5.4-22). Major increases in eagle abundance occurred upstream of the proposed White River Dam site. The differences were largely due to the presence of immature eagles in 1983, whereas in 1982 no immatures were seen. Behavioral patterns of immature bald eagles and, thus, their presence or absence along a particular stretch of river, has been found to be less predictable than that of adults (Grubb and Kennedy, 1981).

During the helicopter survey, two adult and two immature golden eagles, one goshawk (Accipiter gentilis), three red-tailed hawks, two rough-legged hawks (Buteo lagopus), and two unidentified falcons (Falco sp.) were sighted.

Table 5.4-22 Results of bald eagle survey along the White River in winter, 1982 and 1983.

	Cowboy Canyon to Ignatio		Ignatio to WR Dam Site		WR Dam Site to Asphalt Wash		Off the Survey Route	
Year	Ad.	Imm.	Ad.	Imm.	Ad.	Imm.	Ad.	Imm.
1983	7	4	2	1	2	0	6	4
1982	6	0	1	0	3	0	0	0

5.4.6 Mammals

Thirty-three kinds of mammals were observed on or near Ua-Ub during 1983. Five of these mammals were domestic species; cattle (Bos taurus); sheep (Ovis aries); horse (Equus caballus); dogs (Canis domesticus); and cat (Felis domesticus). As usual, the cattle grazed along the White River from June through October. An unusual occurrence during June was the large number of cattle grazing on the lush growth of cheatgrass in shadscale vegetation. Sheep were again present from late November through April. The horses and dogs present were associated with sheep-herders, and the single cat occurred near the trailer camp at Duck Rock. Among the carnivores, coyote (Canis latrans) sign occurred throughout the tracts, striped skunk (Mephitis mephitis) and raccoon (Procyon lotor) occurred along the White River, badger (Taxidea taxus) occurred in the uplands and a long-tailed weasel (Mustella frenata), previously seen in 1976, was observed in Juniper. A western pipistrelle (Pipistrellus hespersus), encountered foraging during the day, was the only bat seen near the tracts.

Further discussion of mammals is divided into three sections: 1) rodents (data from trapping grids), 2) desert cottontails and black-tailed jackrabbits (data from flushing transects), and 3) big game (data from opportunistic sightings and flushing transects).

5.4.6.1 Rodents Seventeen rodent species occurred at Ua-Ub during 1983. No development-related changes in rodents were detected during the year. Notable natural changes in populations were an increase in golden-mantled ground squirrels (Spermophilus lateralis), the invasion of montane voles

(Microtus montanus) in Greasewood, and the vole's increase in abundance in Riparian vegetation. At WG-2 voles were observed in April and June, but they were absent in August, probably due to high summer temperatures and the resultant decrease in fresh grasses, a primary food. In the riparian, voles now occur on all sections of the flood plain from Hell's Hole Canyon to Asphalt Wash. Ord's kangaroo rats, which increased significantly in density in shrub habitats and expanded their range into wooded habitats in 1980-1981, returned to median densities in the shrub vegetation types and were absent in Juniper in 1983. A small population persists at one Riparian site (WR-2) near sandy alluvium deposited by flash floods. Deer mice densities did not increase noticeably in upland areas despite the increase in vegetation productivity. Density in Riparian sites (WR-2 and WR-4), however, was high compared to the historical sampling site (WR-1).

Rodent density, richness, and diversity for all species at Greasewood sites were within established confidence intervals except for diversity at WG-2 (Figure 5.4-31). Similarity in rodent abundance for pairs of Greasewood sites averaged over three years was 75±11 percent for WG-1/WG-3, significantly greater ($p<0.05$) than similarity indices for WG-1/WG-2 (56±15%) and WG-3/WG-2 (53±12%). Similarity of species composition in Greasewood differed less among the sites (WG-1/WG-3 = 79±6%; WG-1/WG-2 = 60±11%; WG-3/WG-2 = 66±14%). The high similarity between WG-1/WG-3 appear to be due to two physical factors: soils and hydrology. WG-2 is located in a small drainage basin of Southam Canyon compared to WG-1, which is along the main drainage of Southam Canyon, and WG-3, which is in the main drainage of Asphalt Wash. Lithic Torriorthent

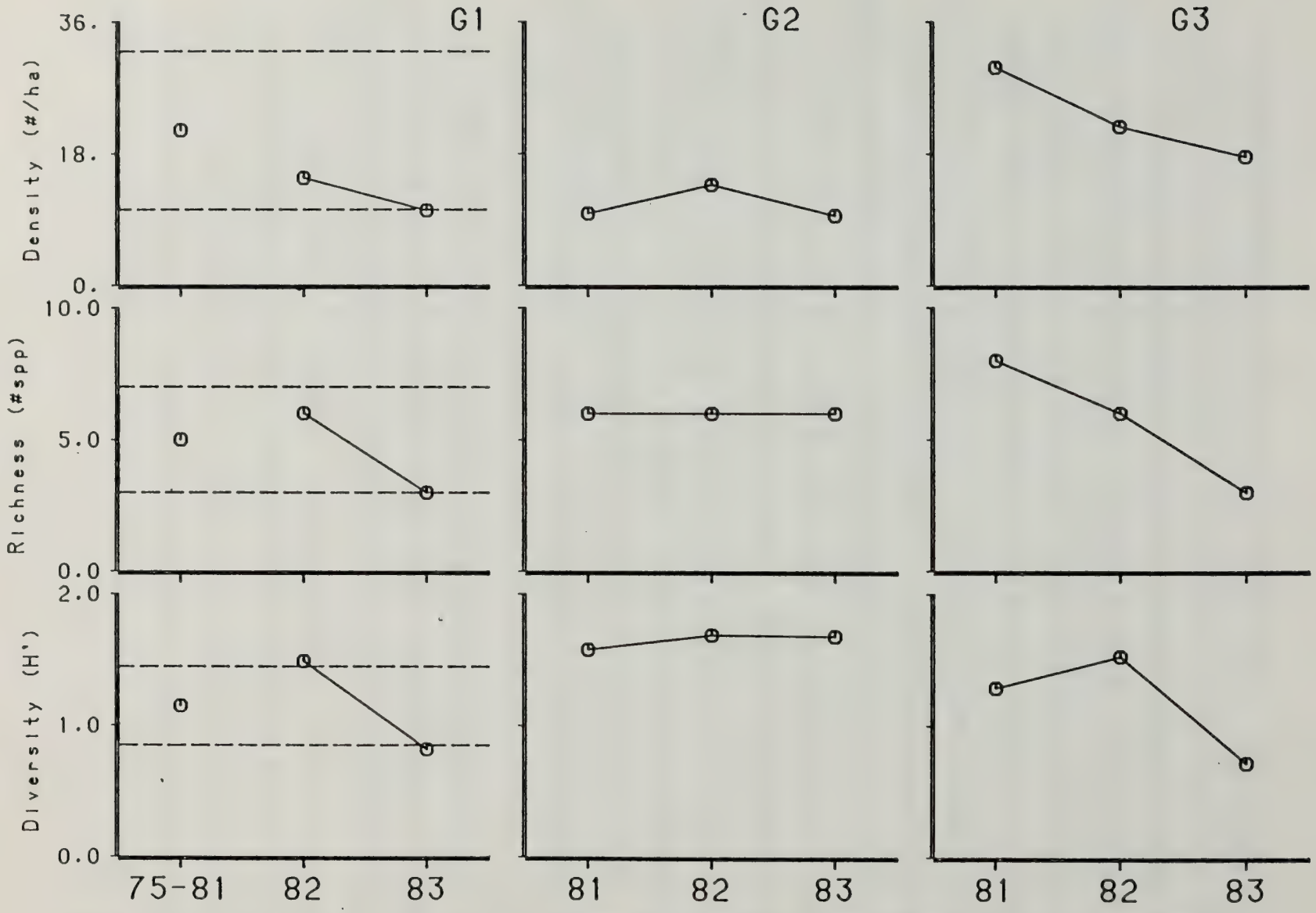

Figure 5.4-31 Density (ind/ha), richness (number of species), and diversity (H') of rodents in Greasewood in August from 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981).

(shallow loamy-skeletal soils) is more common in WG-2 than in WG-1 or WG-3. The effects of subirrigation in WG-1 and WG-3 as well as greater surface flows may influence rodent densities through their effects on habitable dry soils and vegetation productivity. Additional data on vegetation, soil, and hydrological parameters may clarify this relationship.

It is now established that vegetation productivity in one year is strongly correlated with rodent density one year later in all upland habitats: at $r=0.97$ ($p<0.01$) for omnivorous rodents and $r=0.99$ ($p<0.01$) for herbivorous rodents.

Rodent density, richness, and diversity for all species at two Juniper sampling sites were within established confidence intervals for all parameters (Figure 5.4-32). Similarity in rodent density for WJ-1/WJ-5 sites for three years was high ($64\pm7\%$) as was similarity in species composition ($67\pm8\%$). Mining activity at the plant site (WJ-5) had no detectible effect on rodent density compared to undisturbed conditions at WJ-1.

Rodent density at Riparian sampling sites WR-2 and WR-4 far exceeded baseline densities established at WR-1. Nevertheless, the substantial increase in density had little effect on rodent richness and diversity (Figure 5.4-33). The high rodent densities at WR-2 and WR-4 were largely the result of the recent invasion of montane voles. On trapping grid WR-2 the deposition of alluvial material in August 1982 may also have contributed to changes in the density and structure of rodent communities.

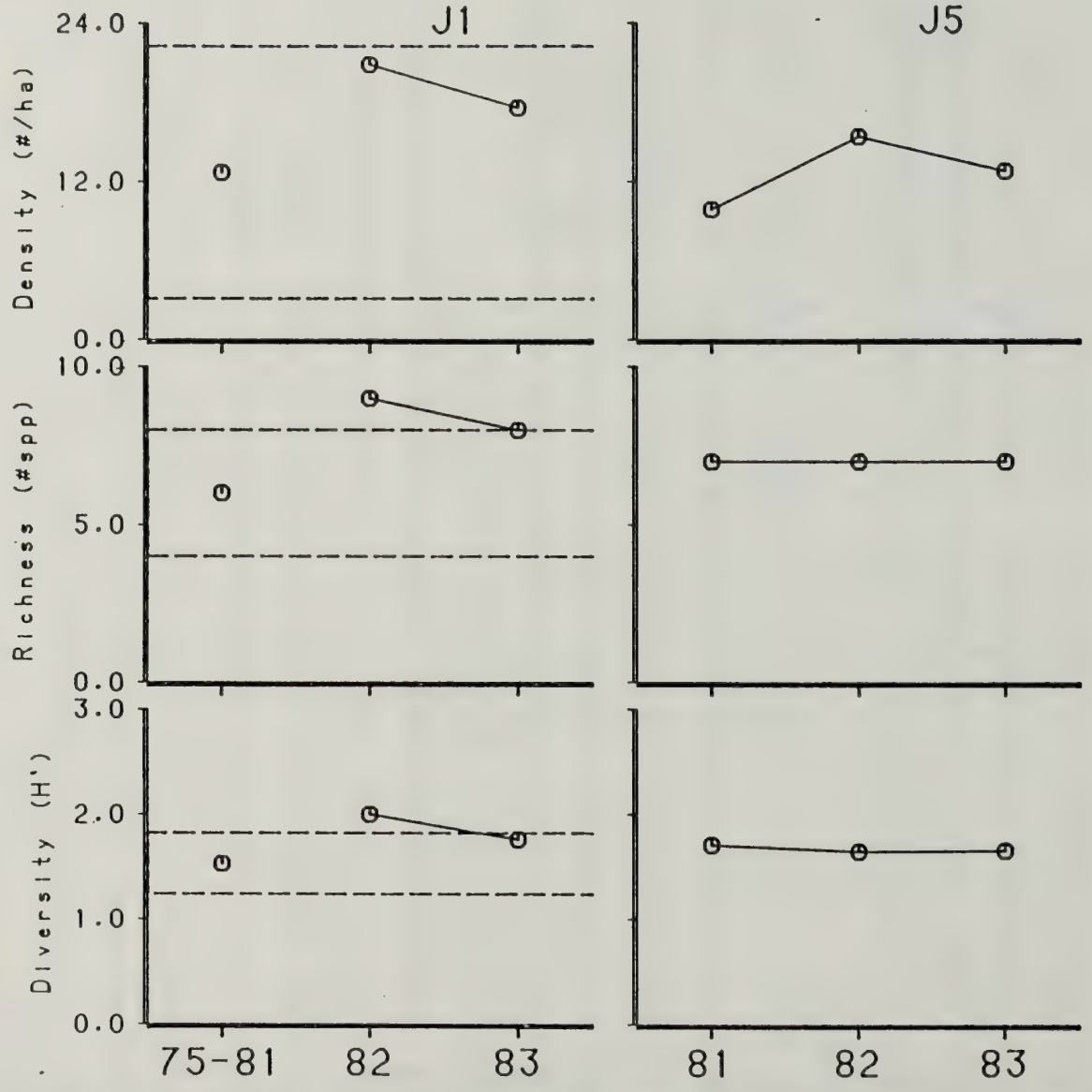

Figure 5.4-32 Density (ind/ha), richness (number of species), and diversity (H') of rodents in Juniper in August from 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981).

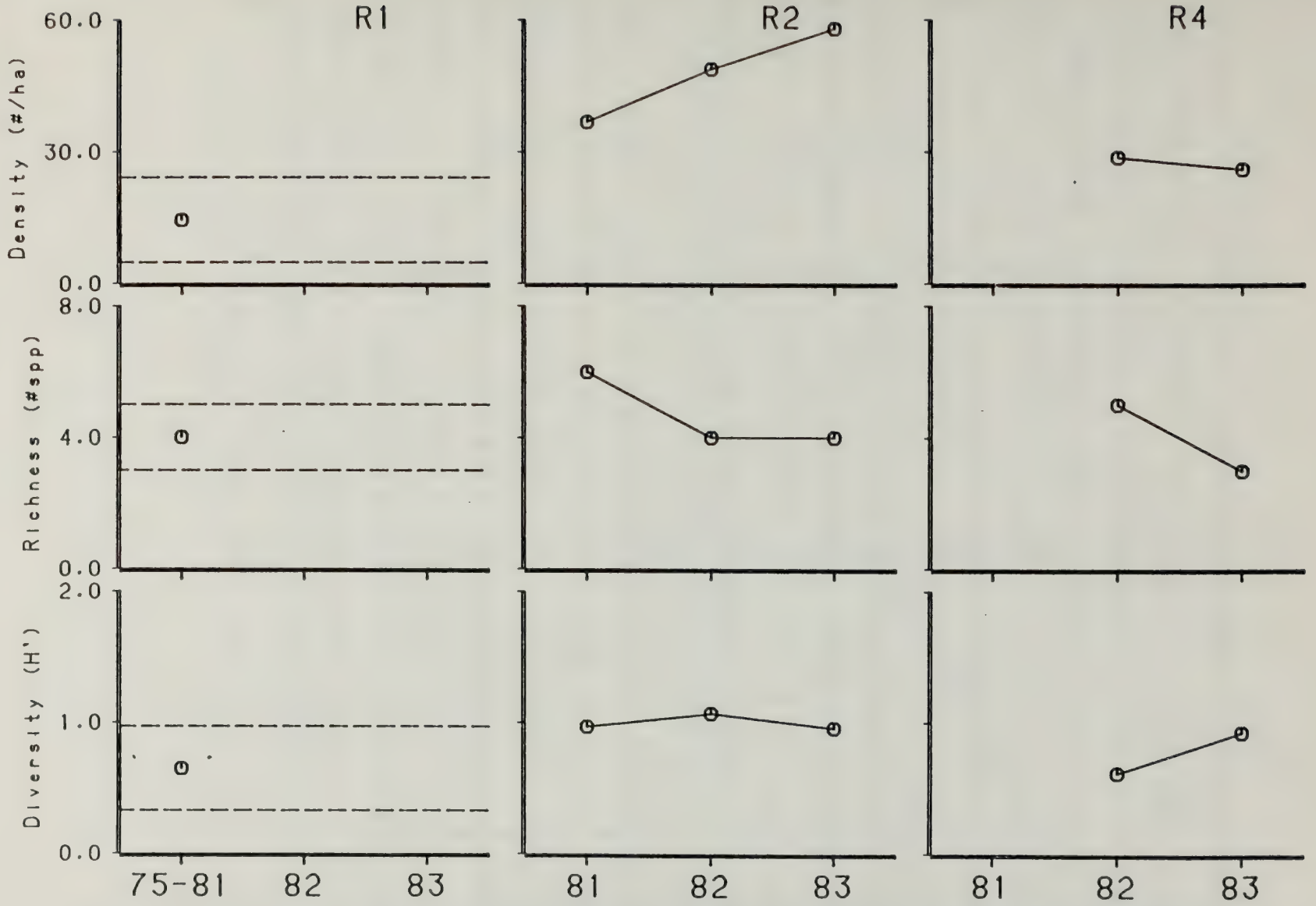

Figure 5.4-33 Density (ind/ha), richness (number of species), and diversity (H') of rodents in Riparian in August from 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981).

Rodent density, richness, and diversity in 1983 were very different at Shadscale sampling sites (Figure 5.4-34). The change in rodent density at WS-4 occurred within the 95% confidence interval established at WS-1, but the decline in richness and diversity at WS-4 was reminiscent of the drought's effect on dents in 1977. Similarity in rodent densities between WS-1 and WS-4 over the past three years averaged 48±13 percent. Similarity in rodent species composition averaged 49±12 percent. These similarity indices were significantly lower ($p<0.05$) than indices for all other shrub site comparisons (e.g., WG-1/WG-3, WG-2/WS-4, and WG-3/WS-1). At the time rodents were sampled at WS-4 (August), a siesmic crew, not associated with oil shale development at Ua-Ub, moved directly through the trapping grid several times in heavy trucks. Since this occurred during the latter half of the sampling session, it is uncertain whether this activity could have contributed to the changes. The amount of siesmic activity on the grid prior to the August sampling session is unknown. An additional source of impact could have been blasting for the highway approximately 500 m from the grid during the fall and winter of 1982. The effects of blasting on fossorial rodents are unknown but may be considerable when blasting is continued over several months as was the case near WS-4. The fact that another sampling site near construction activity and blasting (i.e., WJ-5 located near the plant site) did not differ appreciably from the Juniper control site (WJ-1) argues against this interpretation.

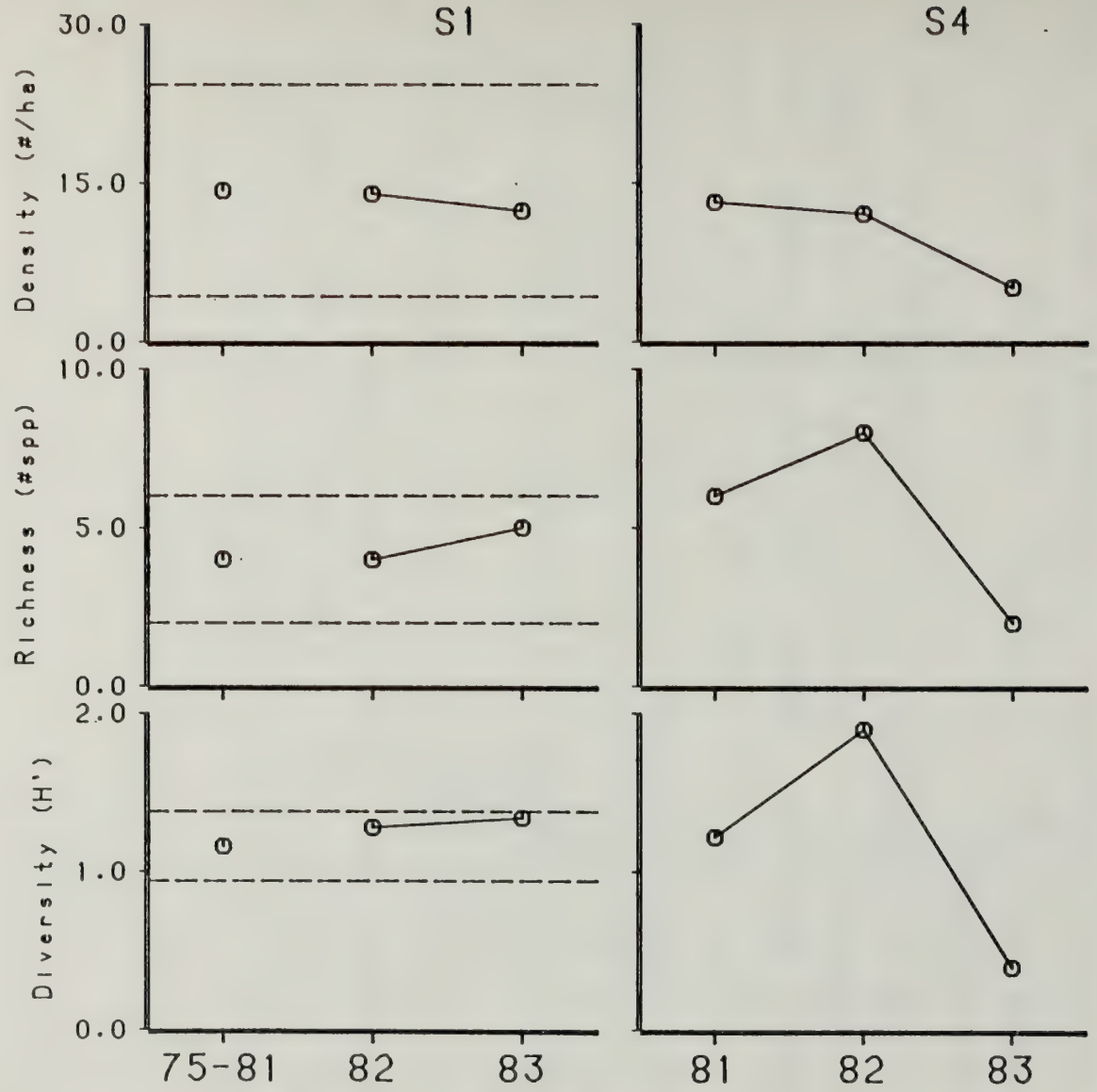

Figure 5.4-34 Density (ind/ha), richness (number of species), and diversity (H') of rodents in Shadscale in August from 1982 and 1983 compared to means (point) and 95% confidence limits (broken lines) during the baseline period (1975-1981).

These results may be due to differences in sites WS-1 and WS-4. Soils at WS-4 compared to all other upland sites are unique (see Section 5.4.1.1). Differences in vegetation composition, cover, and productivity between sites also contribute to the problem. Hence, the disparity in rodent populations at WS-1 and WS-4 are, in part, due to physical differences that influence biological parameters.

5.4.6.2 Desert Cottontails and Black-tailed Jackrabbits. The last two years have seen a population explosion in desert cottontails (Sylvilagus audubonii) (Figure 5.4-35). Compared to 1981 densities, cottontail populations densities in 1983 have increased by 1100 to 2600 percent. In 1976 the cottontail population increased by 300 to 600 percent, compared to 1975 densities. If the cyclic pattern that has been emerging since 1975 continues, cottontail density may remain high in 1984 and probably decline sharply in 1985.

Desert cottontails were more abundant in Greasewood and Riparian (Table 5.4-23), habitats with a lush growth of annual plants. In all habitats, desert cottontails increased in density between April and June (Table 5.4-23), a change that is probably due to high reproduction success in the spring.

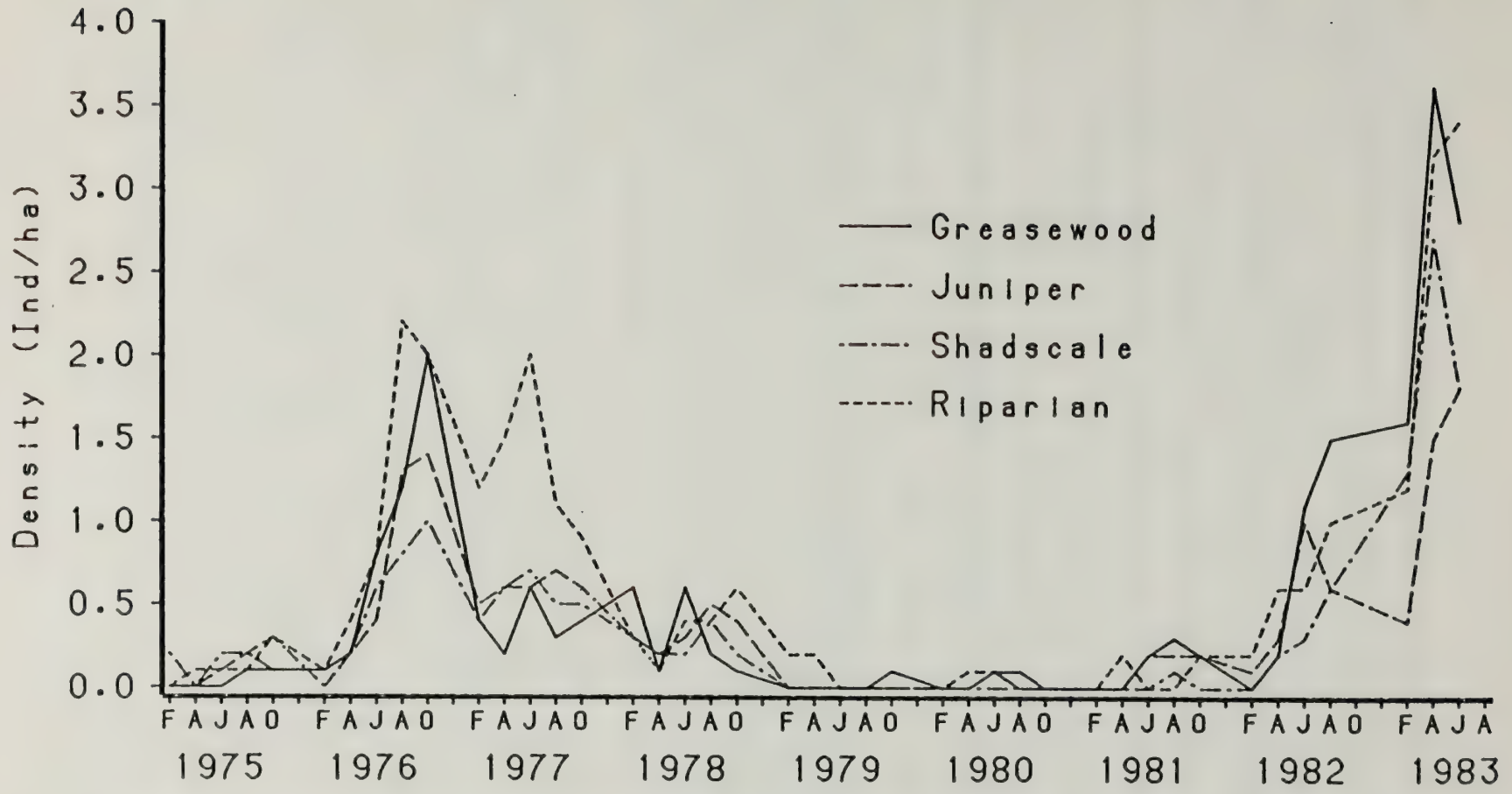

Figure 5.4-35 Density (ind/ha) of desert cottontails in four habitats, bimonthly, from 1975 through 1983.

Table 5.4-23 Densities of desert cottontails (ind/ha) in 1983.

Month	Habitat			
	Greasewood	Juniper	Shadscale	Riparian
April	1.55	0.39	1.29	1.20
June	3.58	1.49	2.65	3.19
August	2.75	1.82	1.82	3.38

Dead cottontails which appear to be untouched by predators, suggest that disease has begun taking its toll. How much of an effect disease and predation have on high density will be dependent on food availability and its nutritive value for cottontails, as well as the severity of the upcoming winter.

Documentation of the highs and lows in lagomorph populations will play a vital role in the timing of revegetation efforts. Ideally, revegetation should begin when the cottontail populations are declining to ensure success in plant establishment. This will give the plants about four years to establish in the absence of cottontail browsing. When plants are available during peak cottontail density, either the plants will be lost or protective measures will increase costs of plant establishment.

For the first time in nine years, black-tailed jackrabbits (Lepus californicus) were observed in all xeric upland vegetation types from Asphalt Wash to Hell's Hole Canyon. Between 1975 and 1982 jackrabbits were encountered only infrequently in the juniper woodland west of Evacuation Creek and east of the main wash of Southam Canyon. In August 1983, Juniper habitat supported 0.6 jackrabbits/km with frequent sightings in Shadscale and Greasewood habitat types. For jackrabbits on Ua-Ub, this appears to be the beginning of a population increase (Gross, et al. 1974), however, it was dwarfed in comparison to the population change in desert cottontails.

5.4.6.3 Big Game The most common big game animal at Ua-Ub are mule deer (Odocoileus hemionus). In 1983 mule deer were seen in small herds in Juniper and Riparian vegetation from spring through fall. Although the low elevation and vegetation at Ua-Ub offers what appears to be adequate winter range, the deer apparently prefer the pinyon-juniper woodlands to the south of Ua-Ub. The pronghorn (Antilocapra americana), which occurs in sizable herds on the plateaus north of Ua-Ub, seldom drops below the upper breaks of the White River canyon, but during the 1977 drought some were seen along the river. In 1983, pronghorn were encountered in the shadscale-covered basin north of sampling site WR-2. Bighorn sheep (Ovis canadensis) were encountered for the first time at Ua and Ub during April and June. A small herd of three ewes was encountered during April along the rocky slopes of Asphalt Wash. In June three ewes, probably the same individuals, were again observed in the cliffs on the north side of the White River near Ignatio Bridge. Previous occurrence of bighorn sheep on the East Tavaputs Plateau is based on a ram's skull

reported by Ranck (1961) and originally recorded by Durrant (1952). Personnel at the Utah Division of Wildlife Resources suggest that the bighorn sheep probably came from Ouray where a small herd is maintained on the reservation.

The number of mule deer appears to have increased in 1983. Fifty-two sightings totaling 191 deer were made in 1983 (Table 5.4-24) compared to 37 sightings of 122 deer in 1982. Along flushing transects, where sampling effort is standardized, thirty-two deer were seen along 135 km of transect in 1983 (0.24 deer/km; Table 5.4-25), whereas in 1982 only 16 deer were seen along 152 km of transect (0.11 deer/km). It is not certain that the deer increase (if real) is due to immigration or reproduction. The lack of fawn sighting in February, April, and June and the high productivity of annual and perennial vegetation in 1983 suggests that deer may have immigrated, attracted by the abundant food resources.

Table 5.4-24 Mule deer observations (both on and off flushing transects) on or near Utah Oil Shale Tracts, Ua and Ub, in 1983.

	Month			
	February	April	June	August
Number of Sightings	3	21	16	12
Greasewood	0	2	2	4
Juniper	1	3	5	4
Shadscale	2	9	4	4
Riparian	0	7	5	0
Number of Deer	22	113	29	27
Bucks	1	0	10	4
Does	6	0	18	13
Fawns	0	0	0	7
Unclassified	15	113	1	3
Mean Herd Size	7.3	5.4	1.8	2.2

Table 5.4-25 Abundance (individuals/km) of mule deer along flushing transects in 1983.

Transect	Months			Total Kilometers Censused	Deer/Km
	April	June	August		
G-1	0	0	0	15	0.00
G-2	0	0	3	15	0.20
G-3	0	0	1	15	0.07
J-1	6	4	0	15	0.67
J-5	4	0	0	15	0.37
S-1	0	1	0	15	0.07
S-4	0	4	5	15	0.60
R-2	0	0	2	15	0.13
R-4	0	2	0	15	0.13
Total Kilometers Censused	45	45	45		
Deer/Km	0.22	0.24	0.24		

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WATER RESOURCES

6.0 WATER RESOURCES

6.1 INTRODUCTION

The water resources monitoring program for the White River Shale Project (WRSP) was initiated in August 1974, and has continued without interruption to the present time. This section of the Progress Report discusses work performed during the period October 1, 1982 through September 30, 1983, which is referred to as the 1983 water year. This program element has been conducted by VTN Consolidated, Inc. of Irvine, California.

The 1983 water year monitoring program involved monitoring of surface water, ground water and hydrometeorology (precipitation and evaporation) on and near the tracts. It also included the documentation of efforts to meet the Quality Assurance and Quality Control (QA/QC) program objectives as described in the Environmental Monitoring Manual (WRSOC 1982), hereafter referred as the EMM, and a technical memorandum (VTN 1982a) for this project. During the past water year, field data collection was performed by WRSOC, under the direction of VTN. VTN was responsible for data reduction and analysis and the preparation of reports for the water resources program.

In addition to the WRSP Monitoring program, the United States Geological Survey (USGS) has been conducting its own water resources data collection program in the southeastern Uinta Basin throughout the project life. During the 1983 water year, the USGS efforts involved collection of streamflow and water quality data in the immediate vicinity of the tracts. The WRSP surface water monitoring program was designed to be used in conjunction with portions of the USGS program to meet monitoring objectives for the project. All USGS data presented in this report (USGS 1984) are preliminary and subject to revision, since they were "provisional" at the time of report preparation.

6.2 SUMMARY

6.2.1 Hydrometeorology

During the 1983 water year, precipitation averaged 13.70 inches across the WRSP tracts. 1983 was the second consecutive year of above-average precipitation. However, no unusual precipitation intensities were measured. The most intense rainfall event (September 30) was representative of a two-year recurrence interval storm.

Fall precipitation was slightly lower than the average for the previous five years, but precipitation was notably higher than average during the winter, spring and summer seasons. Fall and winter were dominated by synoptic-scale storms which resulted in an even areal distribution of precipitation. The areal distribution of spring and summer precipitation was more variable due to localized intense thunderstorm activity.

A climate water balance analysis using the computer model WATBUG was performed for Southam Canyon from March 5 through July 31. Results indicated that soil moisture levels rapidly declined in May and June from the field capacity to the wilting point in response to increased potential evapotranspiration.

6.2.2 Surface Water

The 1983 annual runoff from Evacuation Creek (7,417 acre-feet) exceeded the mean annual runoff for 1975-1982 (1,360 acre-feet) by over a factor of five. The high streamflows were created by heavy snowmelt runoff contributed from the upper Evacuation Creek watershed during March to mid-July. In addition, thunderstorms during July and August caused six high flows (greater

than 100 cfs). Suspended sediment and water quality data collected at Evacuation Creek were very similar to previous years. All water quality variations detected were natural or non-project related, since no project activities have occurred in this drainage.

The effective drainage area of the Plant Site Wash station 6602, was reduced substantially by the completion of the retention dam. A total of 7.3 acre-feet of runoff were recorded in 1983, of which only approximately 1 acre-foot was natural runoff from the area below the dam. The remaining runoff was derived from a mixture of natural runoff and water used in dam construction that had originally collected in the dam cutoff trench. This water was pumped to an unlined pit downstream of the dam, subsequently percolated into the alluvium, and then re-surfaced as streamflow near the gauging station. No water quality or suspended sediment data were collected at Plant Site Wash station 6602 in 1983. The runoff recorded at station 6602 during 1983 probably did not have a noticeable effect on White River water quality conditions, because the river's streamflow at the time was more than 100 times greater than flow passing station 6602.

Runoff in Southam Canyon Wash (station 6610) in 1983 (33 acre-feet), was very close to the 1975-1982 mean annual runoff for this station. Nearly half the total annual runoff occurred from a single thunderstorm event on August 11. The peak flow of 440 cfs on August 11 is the maximum instantaneous peak recorded at this station to date. Maximum daily specific conductance readings from several summer runoff events were within the previously observed ranges.

The USGS streamflow record at Asphalt Wash (station 6625) indicated that 1983 runoff (11 acre-feet) was well below the 1975-1982 mean annual runoff (174 acre-feet). No water quality or sediment data were collected at Asphalt Wash station 6625 in 1983.

Mean annual runoff at White River station 6700 during 1983 (818,862 acre-feet) was the highest observed during the 1975-1983 period. In fact, when compared to the long-term flow record at station 6500 (1924 to 1979), the 1983 mean annual runoff was the second highest recorded. High flows in the White River occurred from late May through early August due to snowmelt-runoff from a heavy snowpack in the mountains of the upper basin. Suspended sediment concentrations recorded at White River station 6700 during 1983 were somewhat higher than observed previously, but the elevated sediment concentration in the White River is considered to be a natural (or non-project related) variation. Values for several water quality parameters at station 6700 exceeded the previous maximum levels observed during baseline. The outliers detected at station 6700 are believed to be due to natural variation. The concurrent instantaneous water quality data collected at stations 6395 and 6700 were also evaluated for project-related impacts by two non-parametric statistical tests. Using a paired-replicates test, three parameters (specific conductance, total dissolved solids and dissolved sodium) showed a significant increase ($P < 0.05$) between stations. However, closer inspection indicated only slight differences between stations for 4 pairs of concurrent samples and a substantial difference for the remaining sample pair on August 30. The contribution of high TDS runoff from a flow event that occurred in Evacuation Creek was likely the cause of the differences between White River stations on August 30. (Such short-term contributions from Evacuation Creek are typical of most years.) The Mann-Whitney U-test was used to determine differences between the sample medians of water quality data for stations 6395 and 6700, and no significant differences ($P > 0.05$) were observed for 1983 data. Thus, it was concluded from these results that no notable project-related water quality impacts to the White River occurred in 1983.

6.2.3 Ground Water

Water levels in the Bird's Nest Zone were within the range observed

during baseline investigations, with the exception of a maximum water level observed at well G-10. This peak is believed to be a natural phenomenon, or possibly related to fluctuations observed at well P-1 in the 1982 water year. These unusual fluctuations at well P-1 probably resulted from excavation blasting during road construction. Variations in observed water quality from baseline conditions occurred at wells G-5 and G-11. The differences in water quality were probably related to variation in sampling methods rather than from project-related impacts.

Water levels and water quality of the Uinta Formation were, in general, normal in comparison with baseline values. However, at well UF-1, water levels and water quality were affected by project-related activities. Specifically, a relatively small amount of water from dam construction activities in Plant Site Wash was introduced into the Uinta Formation. This resulted in a substantial increase in measured water levels and also caused some temporary and localized degradation of natural ground water quality in the Uinta Formation.

In Southam Canyon alluvium, water levels and water quality have remained essentially unchanged from baseline conditions and no project-related effects have been detected since early in the baseline period.

Monitoring wells were installed below the retention dam in August and September, 1983 to monitor ground water conditions in the Uinta Formation and the alluvium of Plant Site Wash at the dam site. Measurements of water levels made immediately following construction indicated that some water, of presently unknown quality, was present in several of the wells. A complete characterization of water level and water quality conditions for these wells will not be available until water levels stabilize and additional measurements and analysis are made in 1984.

6.3 PROGRAM DESCRIPTION

The water resources program has been designed to document and assess potential project-related impacts on the hydrologic environment. To fulfill this objective, the 1983 program continued to collect background (pre-construction) data for tract watersheds and ground water systems which could be, but have not yet been, affected by project development activities (i.e., Southam Canyon Wash). Project activities initiated during the 1983 water year, included construction of the Plant Site retention dam and development of the mine ventilation shaft and decline. The monitoring activities, particularly at stations that could be impacted by these construction activities, were designed to allow identification of project-related impacts by comparing concurrent data to data collected at control stations and/or by comparing current data to previously collected baseline data.

The water resources monitoring stations have been located so as to detect: (1) unplanned point surface discharges, such as accidental spills or leaks from retention dams or impoundments; (2) non-point surface discharges, such as runoff from areas of road construction and other project activities; and (3) point and non-point source seepage into local ground water systems.

This report uses the USGS system of nomenclature for surface water station numbers (8 digits) as opposed to previous reports where dual nomenclature systems were used. For convenience, only the last four digits of the USGS surface water station numbers are used in the text.

6.3.1 Hydrometeorology

The hydrometeorological program is designed to collect and analyze climatic data useful to hydrologists, engineers and reclamation specialists.

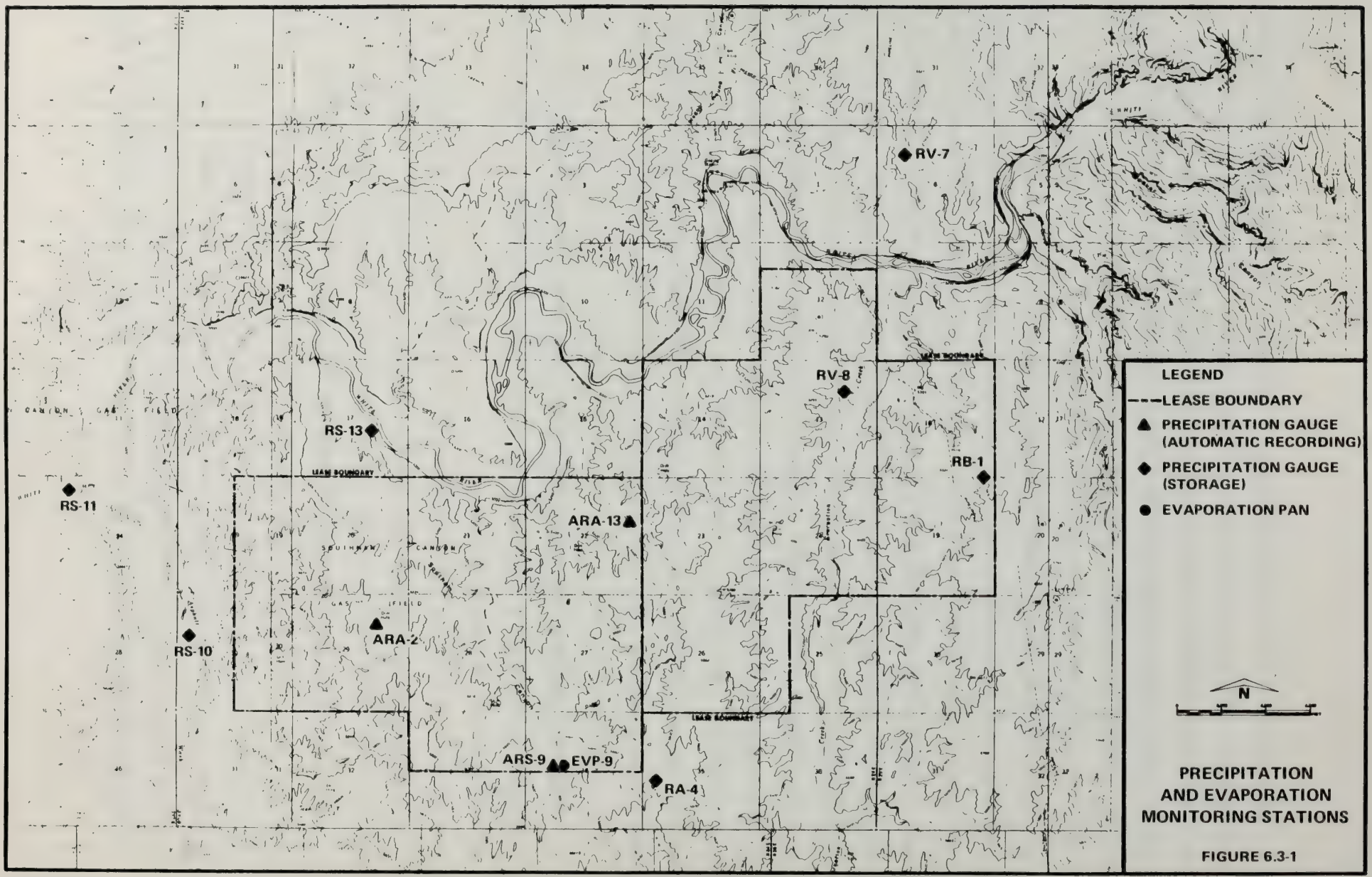
The data provide a record of baseline conditions, document present and past deviations, and are valuable in the interpretation of data in other disciplines. In addition, climatic data are utilized in the design of project activities, such as processed shale disposal, road construction and maintenance, and water harvesting for revegetation projects.

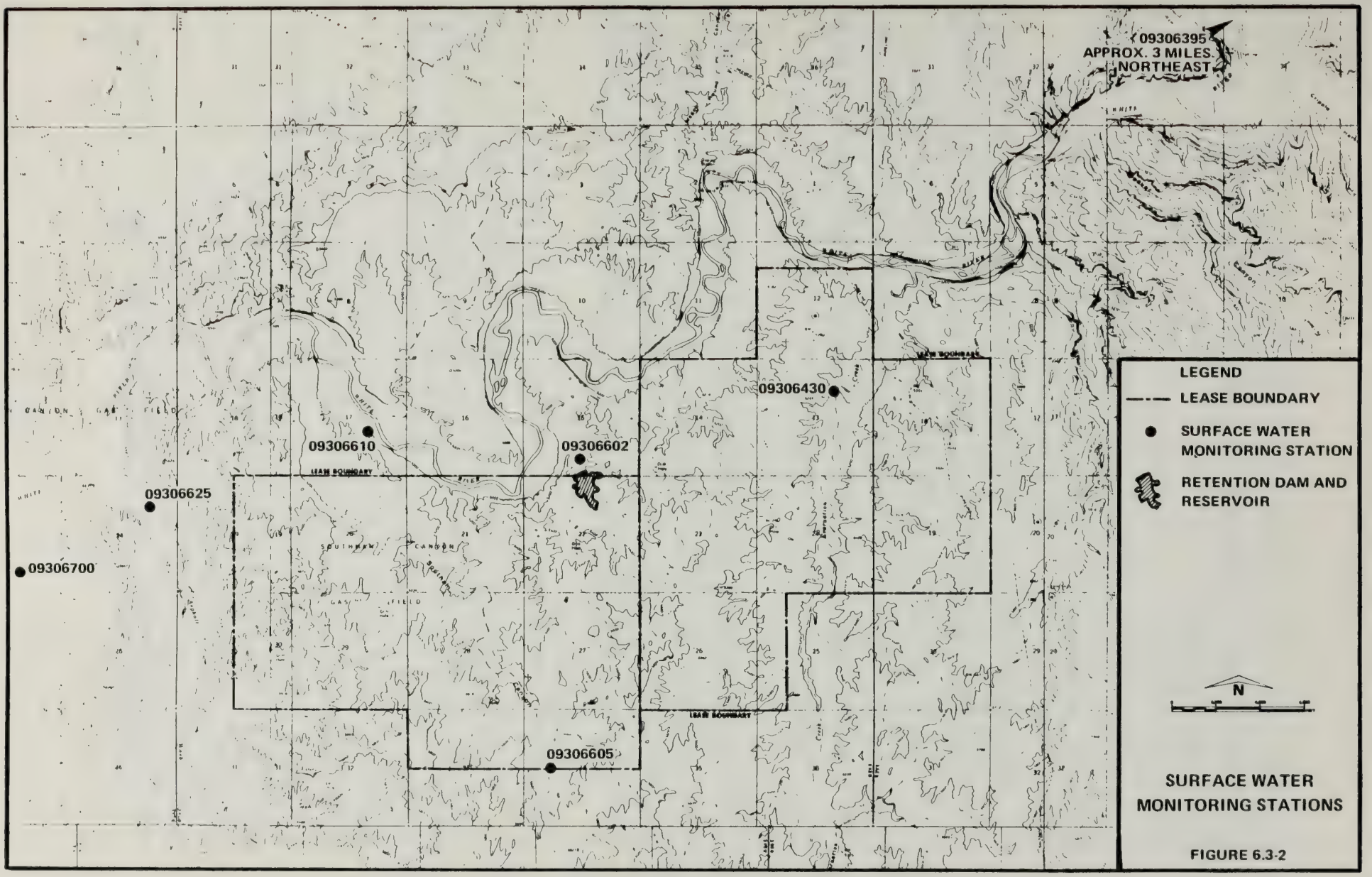
The 1983 hydrometeorological program generally corresponds with the program described in the EMM, as currently revised, except that station EVP-13 was discontinued during construction of the Plant Site retention dam. Also, station EVP-2 was discontinued, relocated and retitled as EVP-9 in Southam Canyon Wash in order to obtain data for nearby terrestrial and vegetation monitoring sites. One new program element for 1983 involved the use of an empirical water balance model (WATBUG). Model results have been interpreted to quantify the soil moisture available for plant growth under varying environmental conditions. A short discussion of the limitations of this method has been included in Section 6.4.1. The locations of all hydrometeorological stations are shown on Figure 6.3-1.

Regional climatic data collected by the National Oceanographic and Atmospheric Administration (NOAA) have also been considered in the analyses of WRSP hydrometeorological data.

6.3.2 Surface Water

The surface water monitoring program is designed to determine the quantity and quality of surface waters surrounding Tracts Ua and Ub. A total of 7 surface water stations were monitored during 1983 (Figure 6.3-2). Stations upstream of WRSP activities (6395, 6605 and 6625) serve as control sites. These stations are unaffected by WRSP activities and monitor natural or non-project related hydrologic events and fluctuations. Stations situated


RV-7
RV-8
RB-1
RS-13
RS-11
RS-10
ARA-13
ARA-2
ARS-9
EVP-9
RA-4
LEASE BOUNDARY
CANYON GAS FIELD
SOUTHERN CANYON GAS FIELD
LEGEND
LEASE BOUNDARY
PRECIPITATION GAUGE (AUTOMATIC RECORDING)
PRECIPITATION GAUGE (STORAGE)
EVAPORATION PAN
N
PRECIPITATION AND EVAPORATION MONITORING STATIONS
FIGURE 6.3-1


09306395
APPROX. 3 MILES
NORTHEAST
09306430
09306610
09306602
09306625
09306700
09306605
LEASE BOUNDARY
LEGEND
LEASE BOUNDARY
SURFACE WATER MONITORING STATION
RETENTION DAM AND RESERVOIR
N
SURFACE WATER MONITORING STATIONS
FIGURE 6.3-2

downstream from project activity (6430, 6602, 6610 and 6700) are designated as treatment stations and monitor the potential effects of project activities in each drainage basin.

The 1983 surface water monitoring program corresponds to that described in the EMM, as currently revised, except for the following differences:

- Continuous records of temperature and specific conductance at Evacuation Creek station 6430 were discontinued because of the poor recovery of data and the lack of project activities in this drainage basin. Collection of continuous stage (discharge), quarterly water quality sampling, and bi-weekly suspended sediment sampling have continued.

- Concurrent (same day) water quality sampling at White River stations 6395 and 6700 was performed to obtain data that were subjected to a series of statistical analyses. New statistical procedures employed can identify chemical or physical parameters that may reflect project perturbations.

6.3.3 Ground Water The objectives of the 1983 water year ground water monitoring program were to: 1) expand the record of background conditions for water levels and water quality in the Birds Nest Zone, Uinta Formation and Southam Canyon alluvium, 2) study possible effects in the Birds Nest Zone due to dewatering and grouting at the mine ventilation shaft and decline, and 3) establish a monitoring well network and monitor possible ground water effects to the alluvium and Uinta Formation in Plant Site Wash following construction of the retention dam.

For most of the water year, a total of 16 wells were used for ground

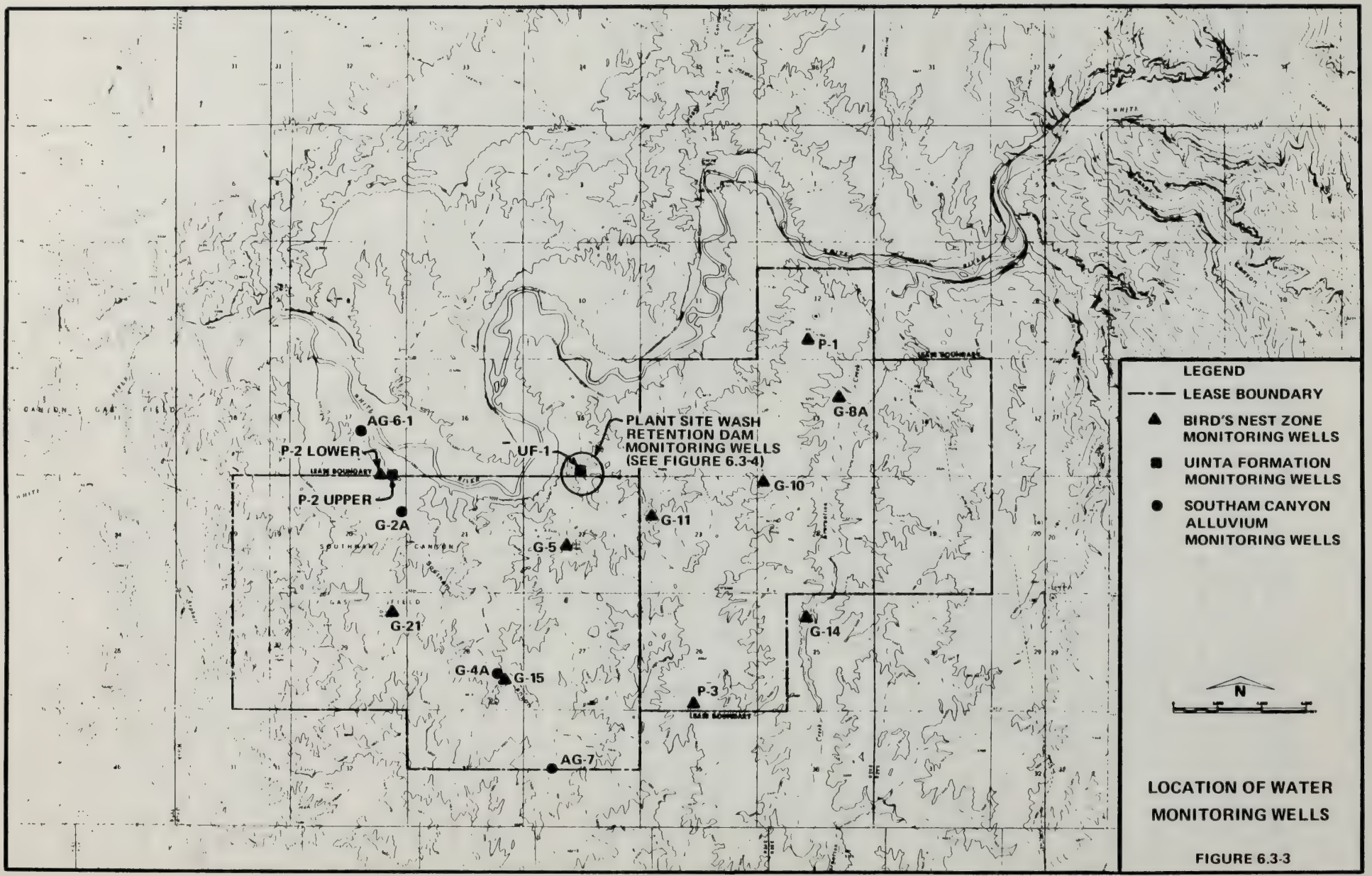
water monitoring. Of these, 10 are in the Birds Nest Zone, two in the Uinta Formation and four in Southam Canyon alluvium. In August and September 1983 seven additional monitoring wells (six of which are multiple-tube wells) were installed in the Uinta Formation and alluvium below Plant Site Wash Retention Dam. The location of all monitoring wells is shown on Figure 6.3-3.

All data collection for the Birds Nest Zone wells was in conformance with the planned monitoring schedule specified in the EMM as currently revised, with the following exceptions: 1) quarterly water levels for the G-wells during January were inadvertently not measured, and 2) a special study involving water quality sampling and continuous water levels was established at wells G-5 and G-11 late in the water year to determine the effects of mine shaft and decline development through the Birds Nest Zone.

All data collection for the Uinta Formation wells was in conformance with the planned monitoring scheduled specified in the EMM as currently revised, except that the data collection program for well UF-1 (drilled in December 1982) was a special study added to the anticipated scope of work.

All data collection for the Southam Canyon alluvium was in conformance with the planned monitoring scheduled specified in the EMM as currently revised, except that water levels and field water quality for all wells in January and for well AG-6-1 in April were inadvertently not made.

Seven monitoring wells were installed in the Uinta Formation and alluvium immediately downstream of the Plant Site Wash retention dam during August and September 1983. At that time, well UF-1 (which was designated a Uinta Formation monitoring well from its completion in December 1982 to August 25, 1983) was decommissioned and recompleted as a multiple-tube well, and is now part of the retention dam well network. The main purpose of the


AG-6-1
P-2 LOWER
P-2 UPPER
G-2A
UF-1
PLANT SITE WASH
RETENTION DAM
MONITORING WELLS
(SEE FIGURE 6.3-4)
P-1
G-8A
G-10
G-11
G-5
G-21
G-4A
G-15
P-3
G-14
AG-7
LEGEND
LEASE BOUNDARY
BIRD'S NEST ZONE
MONITORING WELLS
UINTA FORMATION
MONITORING WELLS
SOUTHAM CANYON
ALLUVIUM
MONITORING WELLS
N
LOCATION OF WATER
MONITORING WELLS
FIGURE 6.3-3

network is to measure ground water conditions and to detect potential leakage from the retention pond. The well locations are shown on Figure 6.3-4.

Water level measurements were made at several of these wells immediately following installation. These initial measurements were made for construction inspection purposes and were not intended for environmental monitoring. The measurements indicate that all wells are correctly installed and functioning properly. A routine monitoring schedule for the retention dam wells has been established and results will be presented in 1984 water year reports. Well installations and data collection procedures were in conformance with reqirements specified by the BLM in July 1983.

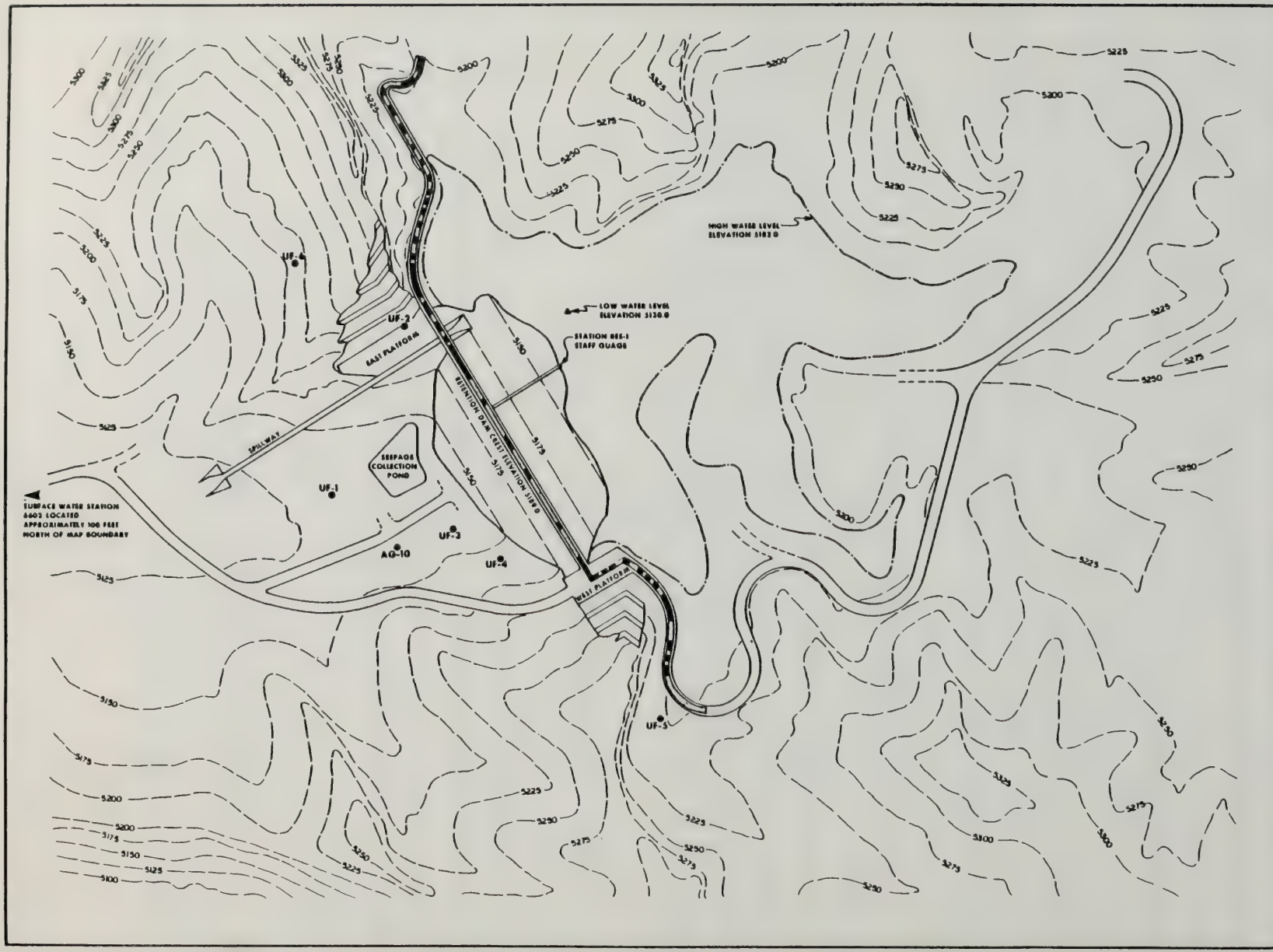
6.3.4 Quality Assurance/Quality Control Program

The purpose of the QA/QC program for the WRSOC water resources monitoring program is to ensure the accuracy, precision, completeness, representativeness and comparability of sampling data. The program design is described in the EMM and in a technical memorandum (VTN 1982a).

6.3.4.1 Field Procedures

A. Methods, Personnel and Equipment Methods employed in data collection throughout the project life were standard methods specified by the USGS and EPA. Personnel involved in data collection and analysis were thoroughly familiar with appropriate methodologies and use of the WRSOC instruments and equipment.

B. Routine Maintenance and Calibration The WRSOC field hydrographer made periodic inspections of the field monitoring equipment. All equipment was routinely checked and maintained to verify that it was in proper working



WHITE RIVER SHALE PROJECT
WATER RESOURCES PROGRAM

PLANT SITE WASH RETENTION DAM AND MONITORING WELLS

LEGEND

- MONITORING WELL
- GROUT CURTAIN, SOLID IN AREAS OF ABOVE-AVERAGE GROUT TAKE (OVER 2.0 SACKS CEMENT PER STAGE)
- HIGH WATER LEVEL IN IMPOUNDMENT, ELEVATION 5182.0
- LOW WATER LEVEL IN IMPOUNDMENT, ELEVATION 5130.0

NOTES:
ELEVATION OF GROUT CAP IS 5185.0' ON ABUTMENTS SLOPING TO 5100.0' BELOW CENTER OF EMBANKMENT

MAP DEVELOPED FROM RALPH M. PARSONS CO. DWGS. 0-72-CE-27, 28, 54, 55, 56 AND RUNOFF RETENTION DAM SITE PLAN (AS BUILT)

N

SCALE 1" = 1200'

100 0 100 200
SCALE IN FEET

DATUM IS MEAN SEA LEVEL

FIGURE 6.3-4

condition. If the equipment did not meet standards or was malfunctioning, immediate action was taken to rectify the problem. Equipment maintenance was performed according to the manufacturers specifications. Records of calibration and maintenance are kept in each instrument's history file.

C. Independent Inspection An independent inspection of WRSOC water resources equipment was performed in September 1983 by WATEC, Inc. of Aurora, Colorado. This has been conducted once a year for the past several years. WATEC's scope of work involved: (1) inspection and calibration of all water quality equipment used in the water resources program, using additional standards and references provided by WATEC, Inc. where possible; (2) inspection of suspended sediment laboratory equipment; (3) inspection of all hydrologic equipment used for the water resources program, such as current meters and stage recorders; and (4) submittal of a report (WATEC 1983) to WRSOC and VTN describing the findings of the audit and corrective actions taken. The WATEC inspection indicated that WRSOC equipment was generally in good condition, with some exceptions.

D. VTN Field Inspections VTN personnel routinely conduct field inspections of the data collection efforts to verify that QC measures were being followed. This involved periodic visits to the project site to inspect the actual performance of the hydrographer(s) and the condition of monitoring stations and equipment. An on-site inspection was conducted during the 1983 water year by each of three VTN discipline specialists in hydrometeorology, surface water and ground water.

6.3.4.2 Laboratory Procedures

A. USGS Central Laboratory The USGS Central Laboratory in Denver, Colorado performed the laboratory analyses for water quality parameters. The

internal QC program of the Central Laboratory involved checking: (1) chemical balance, (2) relation of residue on evaporation to calculated dissolved solids, (3) relation of specific conductance to residue on evaporation, and (4) relation of specific conductance to anions and cations. The QA program involved: (1) performance of time-critical analyses within allowed limits, (2) use and documentation of standard laboratory procedures, (3) use of reference materials to monitor analyses, and (4) analytical review procedures prior to release of information. Additional details are provided in Methods for Determination of Inorganic Substances in Water and Fluvial Sediments (Skougstad, et. al. 1979).

Additional QA procedures were performed by the USGS National Water Quality Laboratory. The Standard Reference Water Sample (SRWS) project team within the National Laboratory conducted an interlaboratory testing program, which involved: (1) distribution of standard reference water samples to participating laboratories for determination of a most probable value for various constituents, and (2) submittal of the standard reference water samples to the Central Laboratory disguised as routine samples received from the various USGS District offices. Results of the analytical evaluation program are distributed to the participating laboratories and those USGS Districts using such outside laboratories. Results of the blind sample program are distributed within the USGS (Janzer 1983).

B. WRSOC Laboratory Laboratory analyses for suspended sediment sample concentrations were performed in WRSOC's site laboratory trailer. The balance used for weighing samples was typically checked on a monthly basis, in accordance with the air resources QC program. Laboratory methods for determination of suspended sediment concentration are standard methods used by the USGS (Guy, 1969).

6.3.4.3 VTN Office Procedures

A. Data Review and Reduction The receipt of all data for the WRSOC water resources program was noted in the WRSOC logbook. The data coordinator reviewed the data to identify and correct any questionable or missing data, and assigned personnel to conduct required tasks. A document control form accompanied all data. This form identified the actions to be taken, the names of the persons who performed the actions and the dates they ocurred. The data and the document control form were given to a discipline specialist or a data technician, depending on the action to be taken.

B. Data Entry and Verification All data entry into the WRSOC water resources data management system was done by a qualified data technician. All data entered manually were verified by another environmental scientist who checked the data entry printout against the original data report. Digital tape data were checked by the appropriate discipline specialist after computer entry. Once checked and found to be correct by the discipline specialist, the data was considered as having been verified.

C. Computer Tabular and Graphical Output Verification All output tables and graphics produced by computer were checked by the author of each section of a report. The outputs were checked against the verified data.

D. WRSOC Data Files All WRSOC water resources data are kept in file drawers with the exception of the digital tapes. The tapes are kept temporarily in a separate two drawer file. After finalization of the records, the tapes are returned to the WRSOC Mine Services Building on the tracts. The files are organized by program, water year, station name and number, and subject (e.g., discharge, rating curves). All non-digital tape data are bound in manila folders.

E. Data Management Audit A quality assurance audit was conducted on the WRSOC data management system. The purpose of the audit was to verify that the field and laboratory data processing and filing was done correctly. For the processing of data, the values reported on reports and forms were compared against the values shown in this Progress Report. The project data files were reviewed to determine if they were maintained in a manner such that the data could easily be retrieved.

An audit report (VTN 1984a) was prepared and placed in the project files. The report discussed the results of the audit and made recommendations for continued monitoring of the WRSOC data management system.

F. Technical Report Preparation and Review Technical reports were prepared by the discipline specialists responsible for the data analysis involved in a particular section of the report. VTN environmental specialists, who had not been directly involved with the data analysis, in turn reviewed these sections for technical accuracy.

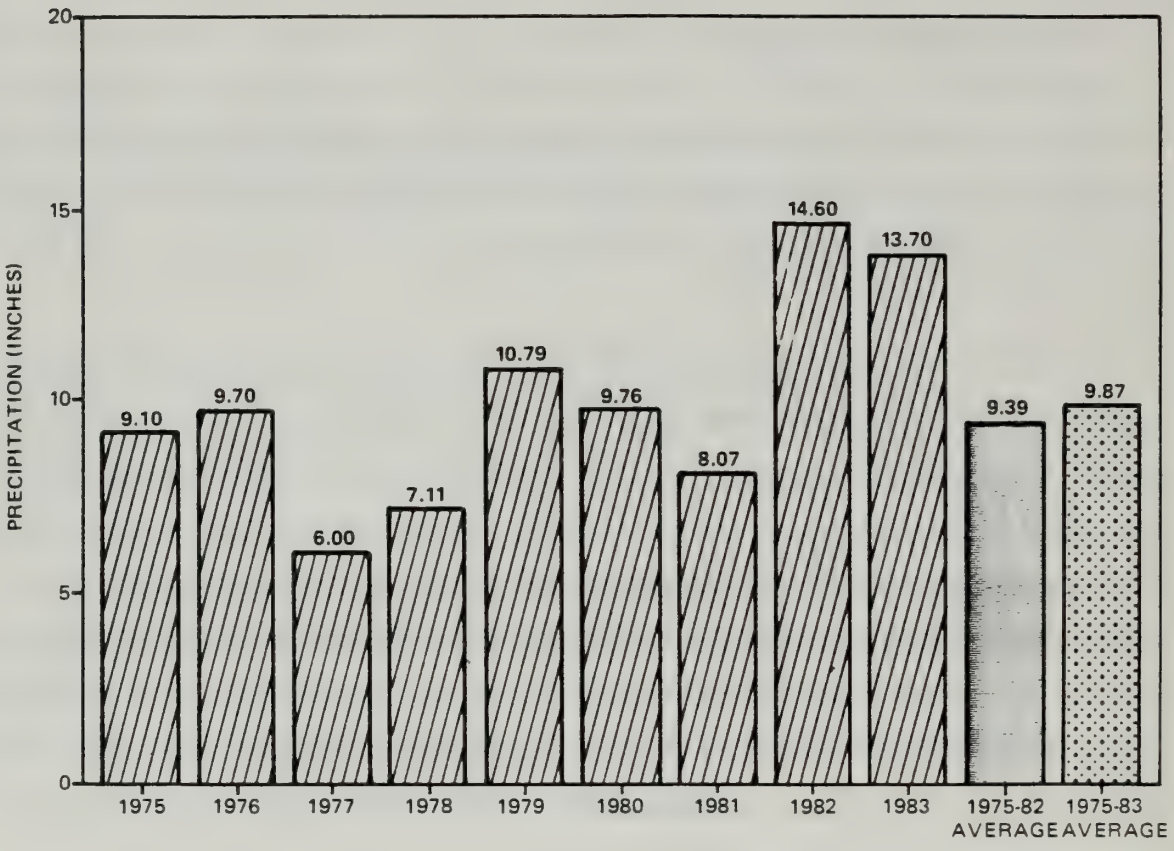
6.4 RESULTS AND ANALYSIS

6.4.1 Hydrometeorology

The following discussion of program results and analysis for the hydrometeorology program is divided into two general categories: Precipitation and Pan Evaporation-Evapotranspiration.

6.4.1.1 Precipitation The 1983 average annual precipitation for the tracts (13.70 inches) was 146 percent of the 1975 through 1982 average annual precipitation (9.39 inches). As seen in Figure 6.4-1, 1983 was the second wettest year recorded by the WRSP monitoring program exceeded only by 1982 (14.60 inches). Figure 6.4-1 depicts the significant deviation from the long-term precipitation average which was first noted in 1982 (WRSOC 1983) and has continued through 1983. This deviation from the norm was also observed throughout the Uinta Basin. For example, the 1983 precipitation totals at Vernal Airport and Jensen, to the north, and Green River, to the south, were 158 percent, 140 percent and 116 percent of 1951-1980 annual precipitation normals (NOAA 1982a, 1982b, 1983).

Of the ten WRSP gauges, the highest annual accumulated precipitation total (14.90 inches) was measured at station RA-4, while the lowest total (11.50 inches) was measured at ARA-13. The high and low stations were consistent with previously established baseline patterns. The range of 3.4 inches in annual accumulated precipitation is not unusual considering the varied nature of storms that cross the tracts and the topographic irregularities of the project area. The standard deviation across the ten-station network was 1.03 inches. No correlation was found between elevation and annual precipitation totals among the ten stations ($R = 0.273$, not significant at 5 percent level).



NOTE: 1975 - 1976 TOTALS BASED UPON 4 STATION NETWORK
1977 TOTALS BASED UPON 2 STATION NETWORK
1978 TOTALS BASED UPON 3 STATION NETWORK
1979 - 1980 TOTALS BASED UPON 8 STATION NETWORK
1981 - 1983 TOTALS BASED UPON 10 STATION NETWORK

LEGEND

ANNUAL PRECIPITATION TOTAL

1975 - 1982 AVERAGE ANNUAL PRECIPITATION TOTAL

1975 - 1983 AVERAGE ANNUAL PRECIPITATION TOTAL

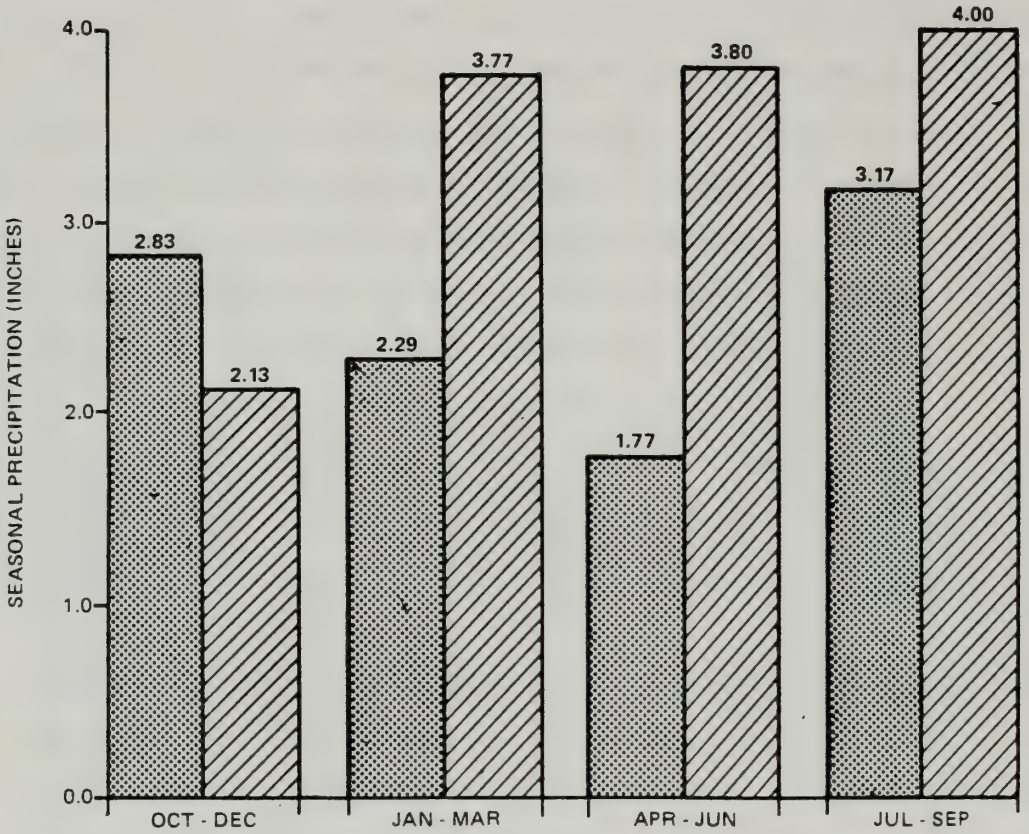
ANNUAL PRECIPITATION TOTALS
WATER YEARS 1975 – 1983

FIGURE 6.4-1

Tract seasonal accumulated precipitation totals and seasonal statistics are shown in Figure 6.4-2. Fall was the driest season, accumulating 2.13 inches of precipitation or 15.5 percent of the annual total. Fall precipitation was 25 percent less than the previous five-year (1978-1982) seasonal average (2.13 vs 2.83 inches). Conversely, winter and spring totals were 65 percent and 115 percent greater than previous five-year seasonal averages (3.77 inches vs. 2.29 inches and 3.80 inches vs. 1.77 inches, respectively). Summer was the wettest season accumulating 4.00 inches of precipitation, which was 26 percent higher than the previous five-year average (3.17 inches). (Note: The seasonal precipitation totals for 1975-1977 have not been included in the above average values because they are not felt to be as accurate as 1978-1982 values in terms of overall tract representativeness.)

The spatial distribution of precipitation varied seasonally across the tracts. Fall and winter precipitation was evenly dispersed across the 10-station network, with minor between-station standard deviations of 0.24 and 0.33 inches and ranges of 0.81 and 1.10 inches, respectively. The uniform distribution of fall and winter precipitation is typical of synoptic storm systems that dominate fall and winter seasons. The distribution of spring and summer precipitation was progressively more variable than fall and winter with standard deviations of 0.42 and 0.70 inches and ranges of 1.26 and 2.30 inches, respectively. Spring precipitation was more variable than fall and winter precipitation due to increased localized thunderstorm activity during late spring. Summer precipitation was the most variable because localized thunderstorm activity was dominant, especially in August and September.

The monthly precipitation tract averages are presented in Figure 6.4-3. January accumulated the lowest monthly total (0.42 inch or 3 percent of annual total) while March accumulated the highest monthly total (2.72 inches



	FALL	WINTER	SPRING	SUMMER
1983 STANDARD DEVIATION	0.24	0.33	0.42	0.70
1983 RANGE	0.81	1.10	1.26	2.30
1983 CORRELATION COEFFICIENT ELEVATION VS SEASONAL TOTAL	–0.044	0.569	0.859*	–0.364
PERCENT OF ANNUAL TOTAL	15.5%	27.5%	28.0%	29.0%

*SIGNIFICANT AT 5% LEVEL

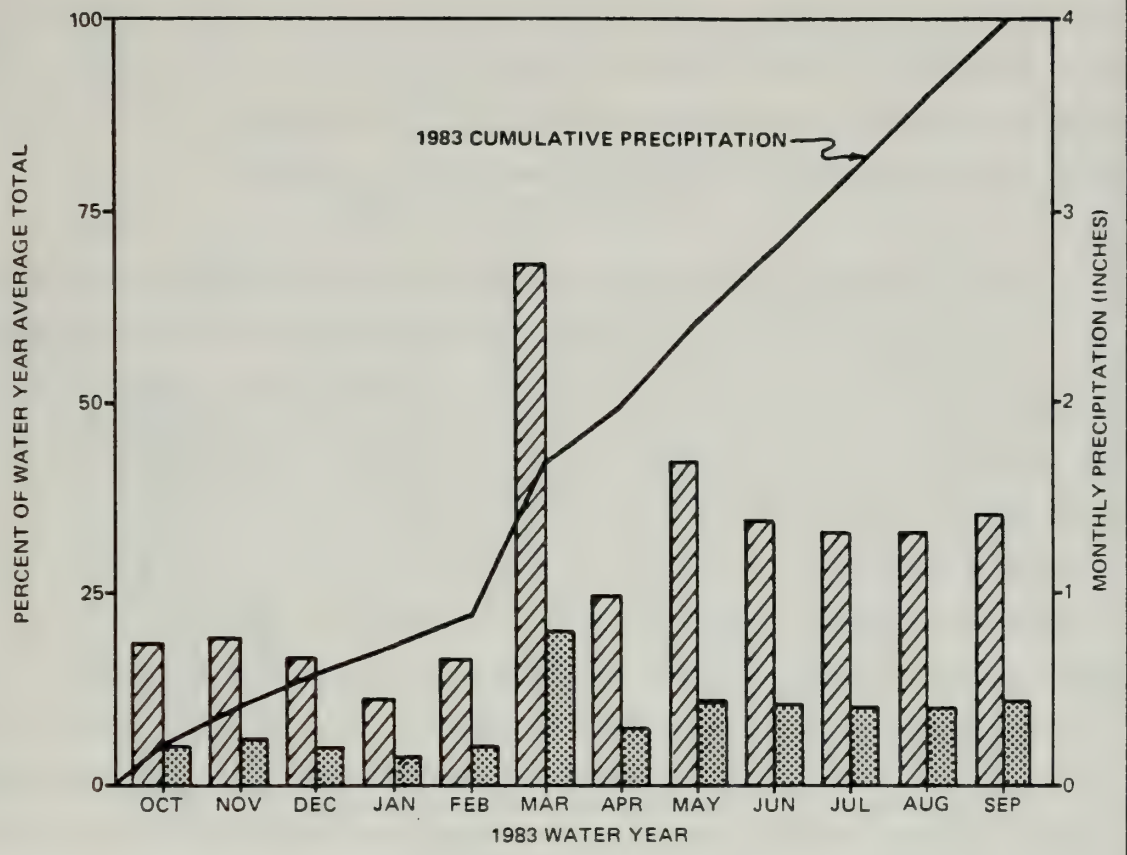
LEGEND

1983 SEASONAL AVERAGES

1978 - 1982 SEASONAL AVERAGES

SEASONAL PRECIPITATION AVERAGES

FIGURE 6.4-2



MONTHLY PRECIPITATION AVERAGES

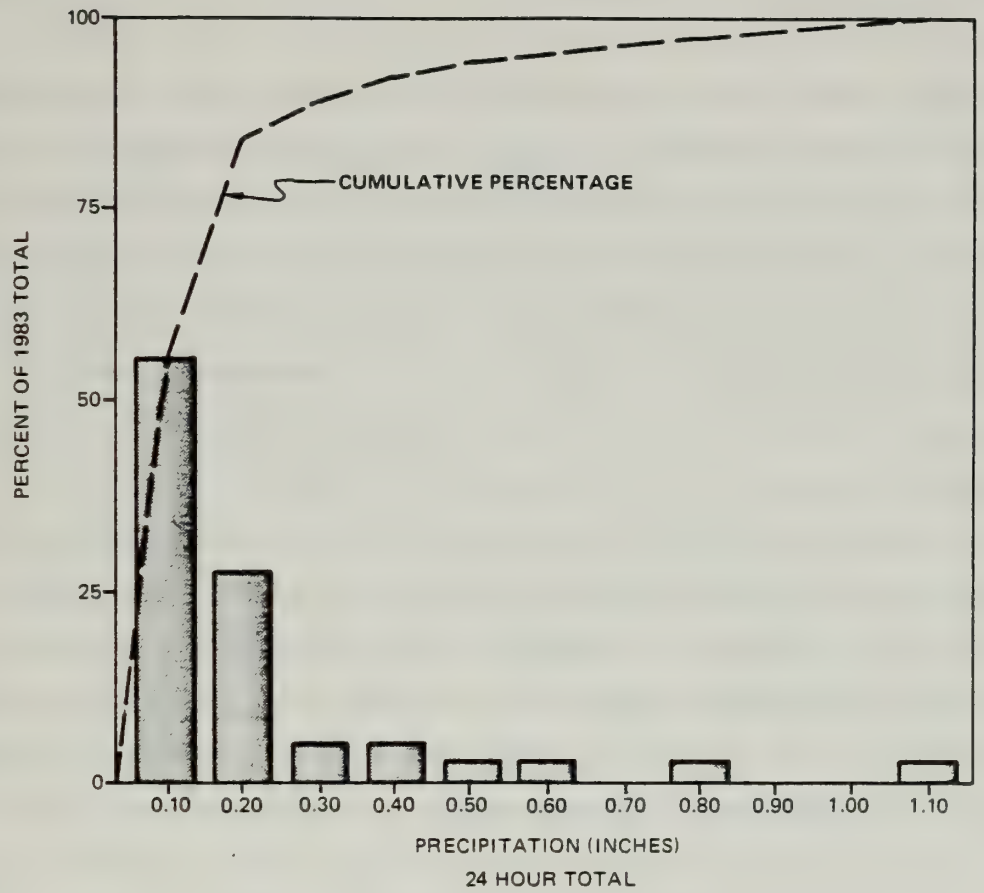
FIGURE 6.4-3

or 20 percent of annual total). As shown in Figure 6.4-3, the accumulated totals for the periods October through February and May through September were relatively uniform (range 0.30 and 0.19 inches, respectively). The monthly distribution of precipitation depicted in Figure 6.4-3 is indicative of the semi-arid climate which typifies the Uinta Basin.

Precipitation was measured year-round in Plant Site Wash at station ARA-13. At this site, a total of 58 days (24-hour periods) received measurable precipitation (0.10 inch or more) during the water year. Forty eight days (83 percent of total) accumulated totals less than or equal to 0.20 inches (see Figure 6.4-4 for a tabulation of precipitation frequencies). The most intense precipitation at ARA-13 was recorded on March 5, with 6-hour and 24-hour accumulated totals of 0.80 and 1.10 inches, respectively. The 1.10 inch 24-hour total was typical of tract precipitation noted in past years and is representative of 24-hour precipitation with a recurrence interval of one to two years (VTN 1982b). The most intense precipitation measured across the tracts was 1.20 inches over 24 hours measured on September 30 at ARA-2. Again, this accumulated total was not unusual with an approximate storm recurrence interval of two years.

Monthly, seasonal and annual isohyetal analyses were performed and are reported in the 1983 Water Resources Field Data Report (VTN 1984b). A tabulation of daily, monthly, seasonal and annual precipitation totals for WRSP sites and regional BLM Uinta Basin precipitation data may be found in the same source.

Three notable rainfall events during 1983 have been selected for discussion. These are typical of tract precipitation events that generate sufficient storm rainfall totals to yield surface runoff. The resulting variations in runoff from these events provides an insight into the interaction of



OBSERVED MAXIMUM PRECIPITATION AT ARA-13 (INCHES)

DURATION	INCHES	DATE
30 MIN	0.30	AUGUST 11
1 HOUR	0.40	AUGUST 11
2 HOURS	0.40	MARCH 5 AND AUGUST 11
3 HOURS	0.50	MARCH 5 AND AUGUST 11
6 HOURS	0.80	MARCH 5
12 HOURS	1.10	MARCH 5
24 HOURS	1.10	MARCH 5

PRECIPITATION FREQUENCIES AT ARA-13

FIGURE 6.4-4

effective precipitation, evapotranspiration, soil moisture and surface runoff in Plant Site Wash and Southam Canyon.

The first notable rainfall event of the 1983 water year occurred on March 5 (1.10 inches at ARA-13). Rainfall lasted approximately 10.5 hours, yielding an average storm rainfall intensity of approximately 0.10 inch/hour. The rainfall originated from a slow moving synoptic scale cold front with a relatively uniform areal distribution of rainfall. High soil moisture conditions probably existed prior to March 5 due to antecedent snowmelt and infiltration, light precipitation and low potential evapotranspiration rates in the preceeding weeks. It is estimated that rainfall began at ARA-13 around 0000 hours (midnight) with the first evidence of discharge in Southam Canyon approximately two hours later at 0200 hours. Only 0.40 inches of moderate to heavy rainfall was necessary to initiate discharge in Southam Canyon. In Plant Site Wash, discharge was initiated six hours after the onset of precipitation after 0.80 inches of rain had accumulated. Differing drainage basin slope, aspect, elevation and antecedent moisture conditions probably account for the longer lag time preceeding discharge in Plant Site Wash. Rainfall ended at approximately 1030 hours. Discharges for Plant Site Wash and Southam Canyon Wash stopped shortly afterwards; between 1000 and 1100 hours in Plant Site Wash and 1300 hours in Southam Canyon. As illustrated by these data, only brief periods of moderate to heavy rain were required to initiate discharge when antecedent soil moisture conditions were at or near field capacity. Rainfall rapidly saturated surface soils, resulting in overland flow, interflow and measurable discharge.

The second notable rainfall event occurred between May 15 and May 17 with a three day total of 0.90 inches at ARA-13 and 1.00 inch at ARS-9. Assuming a tract average rainfall of approximately 1.0 inch, it would be expected that a sufficient quantity of rain fell to initiate discharge

similar to that seen on March 5. However, no discharge was generated in Southam Canyon or Plant Site Wash. The absence of runoff is probably related to the intensity of the rainfall, soil moisture conditions and the high potential evapotranspiration rates which existed at that time. Specifically, rainfall was light (< 0.10 inch/hour) and non-continuous over the three-day storm period, and initial soil moisture levels were below field capacity due to increasing potential evapotranspiration rates in May (see evapotranspiration discussion in Section 6.4.1.2). As a result of these conditions, the light precipitation replenished soil moisture or evaporated, and therefore no overland flow or interflow was generated.

The third storm of interest occurred on August 11. Prior to that date, soil moisture conditions probably were very low, since August potential evapotranspiration rates were high and only 0.10 inch of rain fell in the 10 days prior to this storm. Despite low soil moisture conditions and high potential evapotranspiration, a relatively small quantity of rainfall (0.60 inches measured at ARA-13 over a six-hour period) generated measurable discharge in Plant Site Wash and dramatic discharge in Southam Canyon. These flows were due to the intensity of the localized short duration rainfall, e.g., the intensity during the first hour of this storm was greater than 0.40 inch/hour. Rainfall began at approximately 1945 hours, with peak discharge in Southam Canyon occurring approximately 45 minutes later. Discharge ceased almost simultaneously with rainfall, 4 to 6 hours after initial flows.

The August 11 thunderstorm and flow events occurred when most of the prerequisite conditions for a flashflood were present. Vegetation was sparse and non-continuous, therefore little interception of raindrops occurred; surface soils were poorly anchored; and infiltration rates were low due in part to the low organic content of sandy soils. Large thunderstorm raindrop diameters and fall velocities further inhibited infiltration by splashing

soil particles into natural soil openings. Additionally, the intense short duration rainfall was relatively unaffected by evapotranspiration, and the sheer volume of water introduced over a short period of time exceeded the soil infiltration capacity. Consequently, most rainfall quickly ran off and channelized as discharge in the dry washes.

The rainfall from these three 1983 storms typify tract precipitation events. The rainfall durations, intensities and microclimatic variables affecting soil moisture, overland flow and discharge varied considerably between storm events. Three general observations may be made following the examination of these storm events and environmental variables.

- When soil moisture conditions are high and evapotranspiration rates are low, relatively moderate quantities of rainfall (0.40-0.80 inch) over two to six hours periods may saturate soil moisture conditions and initiate overland flow and discharge. These conditions prevail through late winter and early spring.

- When soil moisture conditions are low or near the wilting point and evapotranspiration rates are high, rainfall of long duration and low intensity may not produce runoff. Storm totals as high as 1.0 inches did not produce runoff in 1983. The probable benefit from such a storm is a temporary recharge of soil moisture. These conditions may be expected throughout spring and summer and early fall.

- The highest amount of runoff for the dry washes on the tracts occur during short duration, heavy precipitation events, e.g., localized thunderstorms. The classic "flashflood" conditions prevail through late spring and summer across the tracts.

6.4.1.2 Pan Evaporation - Evapotranspiration In monitoring the hydrometeorological aspects of WRSP, evaporation from water bodies and evapotranspiration from soil and vegetation are considered. An understanding of evaporation from small water bodies will be critical to the success of the mass balance water budget which is planned for the project's retention pond in the future. An understanding of the evapotranspiration process provides investigators with information, such as available soil moisture, which may be pivotal in the success or failure of reclamation attempts.

Pan evaporation data are intended to simulate the evaporation from open water surfaces, such as small lakes and reservoirs. Pan evaporation data were collected in Southam Canyon at site EVP-9 during the freeze-free period of May through September. These data are presented below.

Date	Pan evaporation
May 3-31	3.87 inches
May 31-June 28	3.76 inches
June 28-July 29	5.78 inches
July 29-August 29	5.02 inches
August 29-September 30	5.94 inches
Total	24.37 inches

No data prior to 1983 exist for site EVP-9. However, previously collected data in Southam Canyon and Plant Site Wash indicate the seasonal total at EVP-9 was typical of previously measured pan evaporation across the tracts through the freeze-free period.

The measurement of evapotranspiration is more complex than measuring evaporation of a small water body and several techniques are available for estimating evapotranspiration. The detailed data required for most of these

techniques are not available at the present time for the WRSP. Sufficient data do exist to run an empirical climatic water balance model (WATBUG) developed by C.W. Thornthwaite Associates (Willmott 1977). The data inputs for the model are relatively simple, therefore conclusions derived from WATBUG should be considered preliminary until more definitive data become available.

The model relies upon the following data inputs: air temperature, site heat index, precipitation (PREC), initial value of soil moisture, soil field capacity and latitude. Model outputs include: potential evapotranspiration (PET), soil moisture storage (ST), change in soil moisture storage (DST), actual evapotranspiration (AET), soil moisture deficit (DEF) and surplus (SURP). The model was run from March 5 through July 31 with a daily time-step. March 5 was selected as the start date because soil moisture levels were at or near field capacity based upon conditions occurring at the site as discussed in Section 6.4.1.1. Also March 5 precedes the season of maximum growth for most annual vegetation types. July 31 was selected to span the season of maximum plant growth for annual vegetation types. Also, by July 31 soil moisture is believed to be at or below the wilting point as the potential evapotranspiration rate reaches its maximum.

The model was run incorporating 1983 climatic data collected principally at ARS-9, with support data from ARS-13 and the air resources station A-11. A one-dimensional sandy loam soil type was assumed with a depth of one foot and an initial soil moisture level at field capacity (2.0 inches of water per foot of soil [Donahue, Miller and Shickluna 1977]). A monthly summary of WATBUG output (inches) is presented in Table 6.4-1 and a diagram of the water balance is shown in Figure 6.4-5.

Potential evapotranspiration (PET) and actual evapotranspiration (AET) rates were initially low, corresponding to low solar insolation input and

TABLE 6.4-1

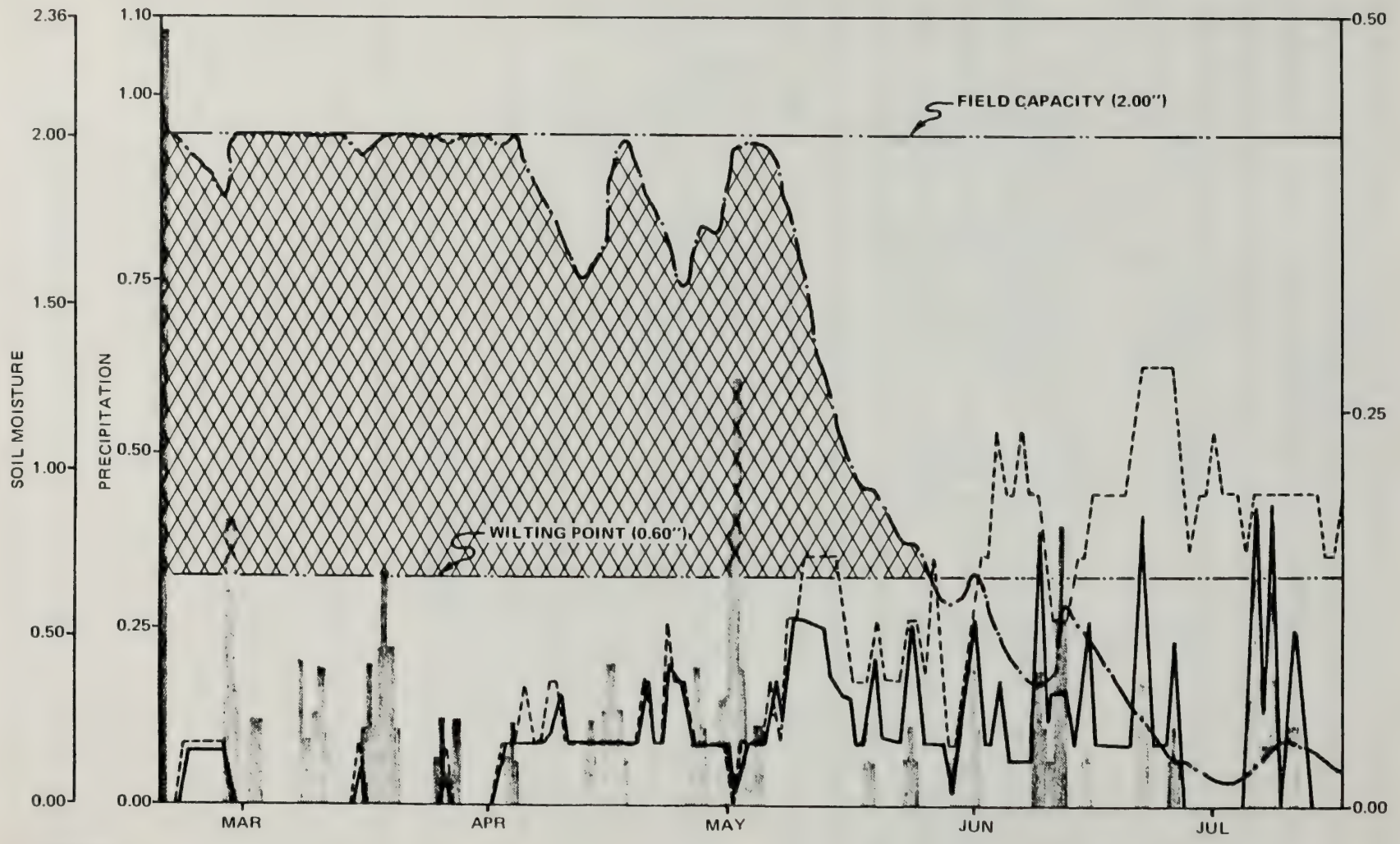
MONTHLY SUMMARY WATER BALANCE

March 5 - July 31, 1983

Date	PET	PREC	ST	AET
			Begin End	
March 5-31	0.28	2.20	2.00 - 2.00	0.28
April 1-30	0.71	1.10	2.00 - 1.81	0.67
May 1-31	2.24	1.60	1.97 - 0.98	1.81
June 1-30	4.02	1.30	0.94 - 0.47	1.81
July 1-31	6.38	1.00	0.43 - 0.11	1.34
March 5-July 31	13.60	7.20	2.00 - 0.11	5.91

Note: The units for all values in this Table are inches of water.

PET = Potential Evapotranspiration
PREC = Precipitation
ST = Soil Moisture Storage
AET = Actual Evapotranspiration



NOTE: ALL VERTICAL MEASUREMENTS ARE IN INCHES.

WATER BALANCE MARCH 5 – JULY 31

SANDY LOAM SOIL TYPE

DATA COMPOSITED FROM SEVERAL MONITORING SITES ACROSS WRSP AREA

FIGURE 6.4-5

resultant low air and soil temperatures. The March through May PET and AET rates were nearly identical, because ample moisture was available for evapotranspiration due to the high soil moisture level. Soil moisture levels near field capacity were maintained until May when PET rates dramatically increased due to increasing energy input. As energy input increased and soil moisture storage decreased, PET and AET began to differ by increasing margins. This break point may be seen between May and June in Figure 6.4-5. As soil moisture levels approached the wilting point in early June, AET no longer reflected the potential rate but mirrored precipitation. With low soil moisture storage, precipitation represents the only moisture source for evapotranspiration. Despite the large quantities of rainfall in summer (see Section 6.4.1.1), soil moisture levels remained low due to the high PET rate. Available soil mositure is shown by the cross-hatched area in Figure 6.4-5. Ample moisture was available March through mid-May for shallow rooted annual vegetation growth. However, low air and soil temperatures March through early April might have been prohibitive to growth. Thus, the effective growing season for annual vegetation was limited to the period between cold air and soil temperatures of April, and low soil moisture levels in early June.

Despite the interesting results noted above, several severe limitations to the WATBUG method must be realized.

- WATBUG is a generalized climatic model. Site specific microclimatic data, such as wind speed, relative humidity and aspect are not considered.

- The model does not allow for short term (less than 24 hour) soil moisture recharge and its subsequent use by plants. For instance, short duration rainfall may be critical, temporarily raising soil moisture levels and thus allowing seed germination or spurts in plant

growth. Such short-term utilization of moisture is beyond the scope of WATBUG.

- WATBUG assumes all precipitation is utilized in recharging soil moisture levels unless the soil is saturated. As shown in Section 6.4.1.1, conditions may exist such that runoff can occur before soil moisture levels are raised to saturation.

- WATBUG assumes a one-dimensional soil layer. A one-dimensional soil model can be appropriate in soil moisture determinations for shallow rooted annual vegetation types. However, in the case of deep rooted perennial vegetation types, a one-dimensional model may not be appropriate.

Undoubtedly other criticisms may be leveled against the WATBUG method. However, as seen in Figure 6.4-5, its utility lies in the fact that information is provided for a site from relatively simple data inputs.

6.4.2 Surface Water

The following discussion of program results and analysis for surface water data is divided into sections according to drainage basin. Each section presents specific discussions of streamflow, suspended sediment and water quality.

Projected-related activities during 1983 were primarily restricted to the Plant Site Wash drainage. Only very minor solid waste disposal activities in a small area of upper Southam Canyon (on-tract) occurred during 1983, and probably did not affect streamflow, sediment or water quality characteristics of this drainage. The Asphalt Wash and Evacuation Creek watersheds

were not disturbed by project-related activities during the year. Of the surface water stations currently operated, only station 6602 in the Plant Site Wash and station 6700 on the White River downstream of the tracts, should be considered as potentially having been affected by construction activities. The remaining stations are still measuring background conditions unaffected by the WRSP.

Throughout this section, comparisons will be made between 1983 data and previous records. Generally, the entire period of record is used in comparisons for streamflow data, and the baseline (pre-construction) period, 1974 or 1975 through 1981, is used for suspended sediment and water quality data. The rationale is that streamflow regimes (excluding that for Plant Site Wash) which have not yet been notably affected by project activities require the use of all available previous records for historical comparisons. However, the analyses for suspended sediment and water quality data require that current-year data be compared to baseline data, as stipulated in the EMM.

Water resources data collected during 1983 were analyzed for possible project-related impacts by two general statistical procedures: (1) identification of outliers from the normal (baseline) range of values, and (2) determination of significant differences in water quality characteristics between control and treatment stations. The statistical tests implemented, the limitations involved, and the proposed revisions for future analyses, are discussed in more detail below.

Identification of outliers provides a means of "flagging" those instantaneous or daily values requiring additional analysis. Outliers are defined as those values exceeding a baseline-defined maximum, falling below a baseline minimum, or falling outside of baseline confidence limits. If outliers were determined, a hydrographic analysis and further statistical tests of the suspect data values were conducted. To initially identify outliers, the 95

percent confidence limits for instantaneous values were computed for water quality data from the baseline period (1975 to 1981). If current-year water quality values exceed the upper confidence limit for that parameter (or the lower confidence limit for pH and dissolved oxygen), the values are considered outliers from the normal range of values.

For the continuous (daily) records collected at White River station 6700, the 99 percent confidence limits were used to identify outliers. Selection of the 99 percent confidence limit is suggested for large data sets (greater than 100) such as these (Sokal and Rohlf, 1969). Comparison of current-year data for specific conductance and water temperature collected at White River station 6700 to the 99 percent confidence limits of the baseline record (1975-1981) easily identified those values that were outside their normal range.

Statistical testing between control and treatment stations was used to show significant differences ($P < 0.05$) that might be attributable to project activities. Due to the small sample size ($n = 5$) of 1983 instantaneous water quality data, non-parametric statistical analyses were conducted. The non-parametric analyses involve the paired-replicates test and the Mann-Whitney U-test.

The paired-replicates statistical test is used to determine pair-wise variations between control and treatment stations. In order to implement this test, concurrent (same day) samples were collected on five occasions at White River stations 6395 and 6700 during 1983. The paired-replicates test is used for determining consistent trends in the paired data; i.e., that one station is always greater than the other. The magnitude of the difference between values does not affect the results. For those parameters exhibiting a significant difference between stations, a potential project impact would

be suggested. Further analysis would be required to determine whether the high values were actually project-related.

The Mann-Whitney U-test was used for comparison of sample medians. This test was also run on concurrent water quality data collected at control and treatment stations to verify the results of other tests.

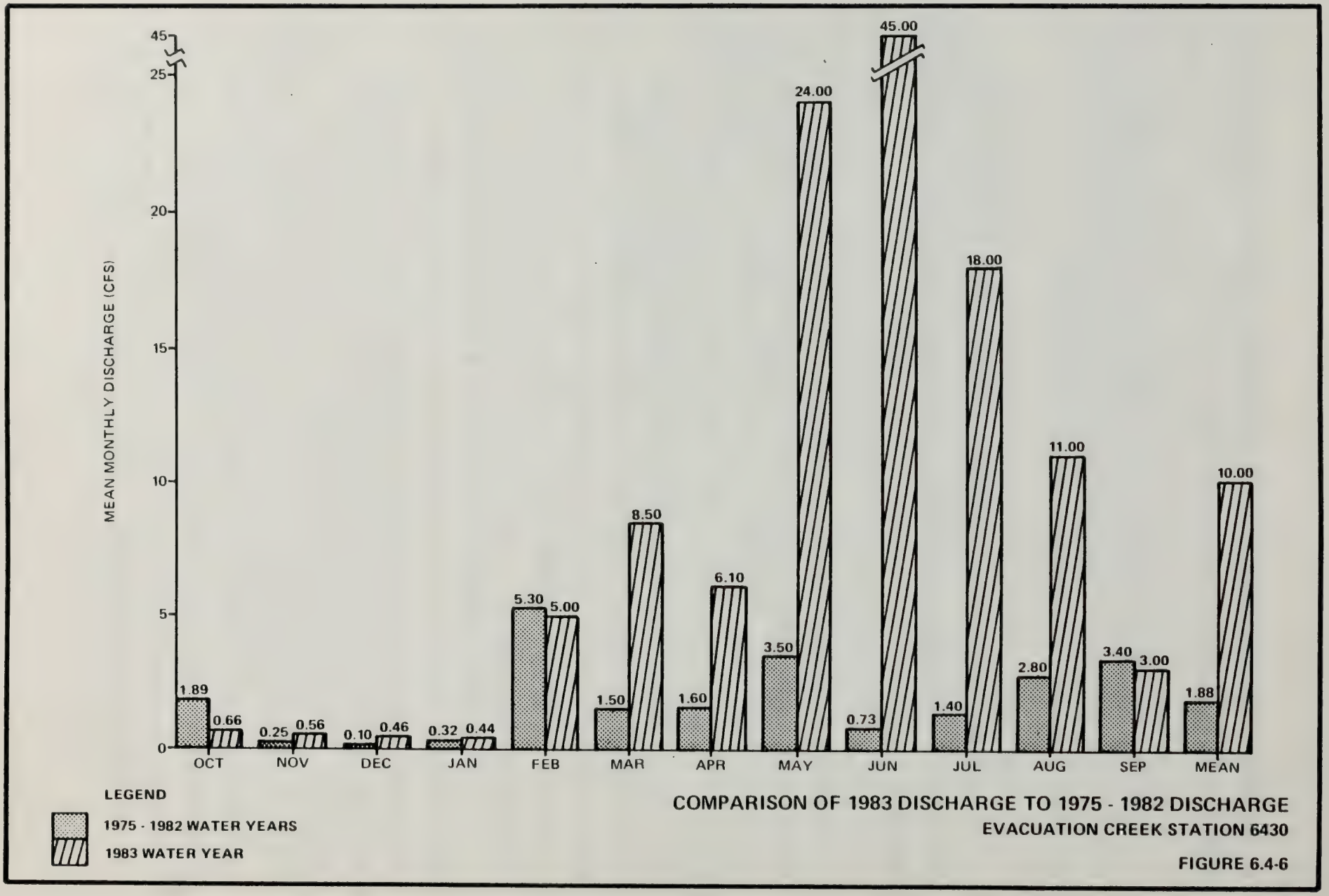
The paired t-test was implemented to determine the difference in concurrent mean daily specific conductance values between White River stations 6395 and 6700.

Rigorous use of the three statistical tests utilizing concurrent data between White River control and treatment stations has been limited because of inflows from Evacuation Creek. This will be eliminated in the 1984 program by moving the White River control station to a new site below the Evacuation Creek confluence. This new control station site is still above the point where water related impacts from the WRSP are expected to occur.

6.4.2.1 Evacuation Creek

A. Streamflow The mean monthly discharge of Evacuation Creek during the 1983 water year is shown in Figure 6.4-6. Mean annual discharge for the 1983 water year was 10 cfs, and total annual runoff was 7,417 acre-feet. This was, by far, the greatest observed during the 9 years of streamflow records at this station and greatly exceeded the 1975-1982 mean flow of 1.88 cfs. The increased runoff was due to well above normal discharges from March through August. This observation can be easily observed in Figure 6.4-6 which compares mean monthly discharges for 1983 to 1975-1982 means.

The Evacuation Creek baseflow period of October to mid-February was in



COMPARISON OF 1983 DISCHARGE TO 1975 - 1982 DISCHARGE
EVACUATION CREEK STATION 6430

FIGURE 6.4-6

the normal range during 1983. However, an extremely heavy winter snowpack in the mountains of the upper Evacuation Creek drainage began melting in late February and created high flows that extended well into July. The peak snowmelt period occurred in June with a mean monthly flow of 45 cfs. In comparison, the 1975-1982 mean flow during June was only 0.73 cfs.

In addition to the extremely high snowmelt runoff, the thunderstorm runoff during July and August was also above normal. Major runoff events (greater than 100 cfs) occurred on July 21, 26, and 31 and August 10, 12, and 30. The maximum peak instantaneous discharge recorded in 1983 was 740 cfs on July 21.

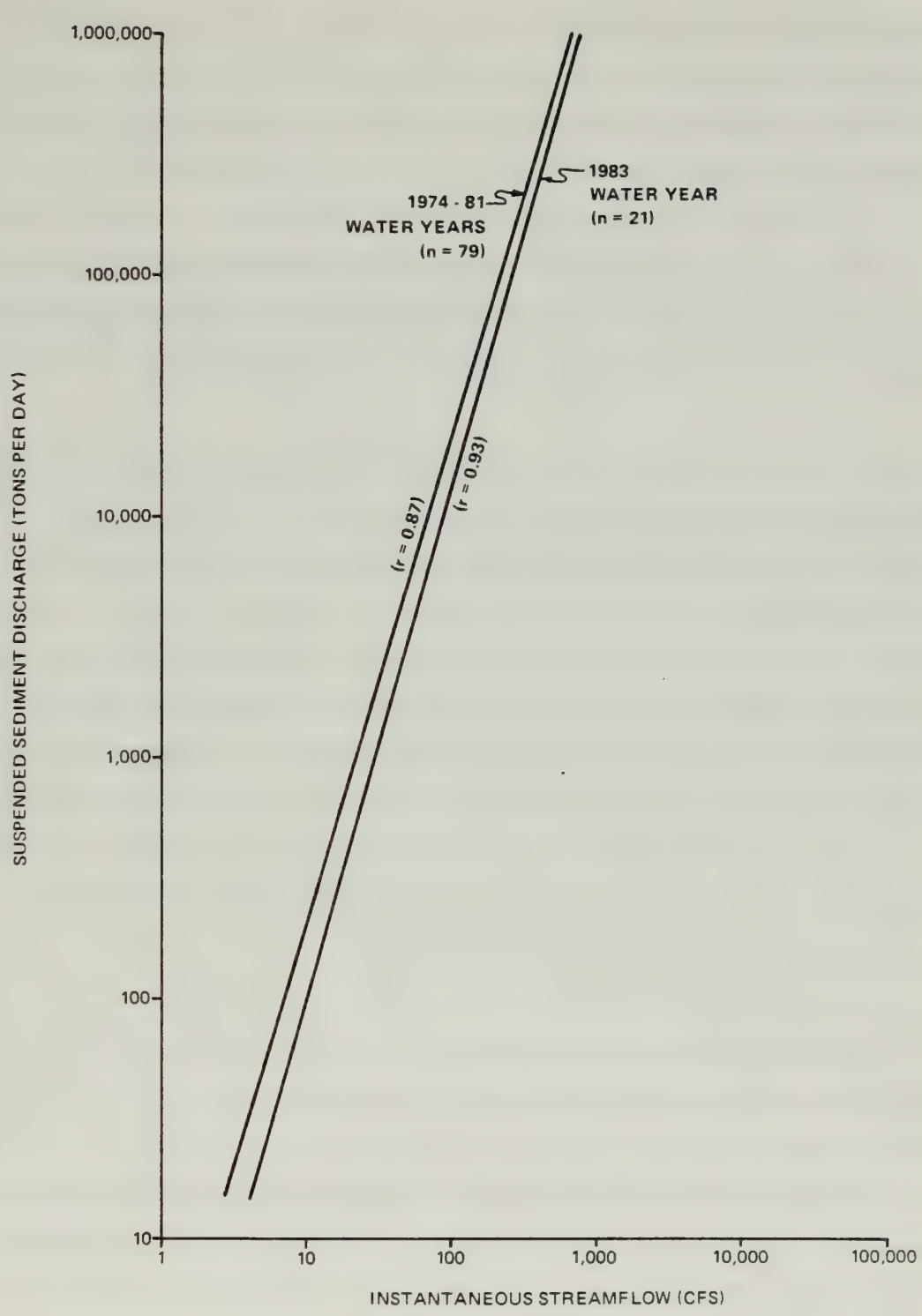
B. Suspended Sediment Instantaneous suspended sediment samples were collected at Evacuation Creek station 6430 on 32 occasions during the 1983 water year. The concentrations of suspended sediment ranged from 59 mg/l to 57,500 mg/l (see Table 6.4-2). This wide variation in sediment concentration is typical of Evacuation Creek due to the extreme range in streamflows.

As observed in previous years (1974-1981), the suspended sediment concentrations during 1983 increased substantially during high flow periods (see Figure 6.4-7). Suspended concentrations during the baseflow period of October 1 to February 16 were very low, ranging from 59 mg/l to 247 mg/l. During the extremely high snowmelt runoff period (late February through mid-July) sediment concentrations increased substantially (544 mg/l to 9,560 mg/l). On June 3, the highest 1983 sediment concentration of 57,500 mg/l and the greatest streamflow of 73 cfs, were measured. However, this maximum sediment concentration is much less than the maximum concentrations of previous years. For example, in 1977 sediment concentrations of 178,000 mg/l and 164,000 mg/l were measured during peak storm events. Periodic thunderstorms during the July to September period of 1983 also caused short-term

TABLE 6.4-2
SUSPENDED SEDIMENT AND FIELD WATER QUALITY DATA
FOR EVACUATION CREEK STATION 09306430

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	SEDI-MENT, SUS-PENDED (MG/L)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)
10/04/82	0915	1.0	123	3600	10.5	8.3	7.8
10/13/82	1000	E0.58	—	3900	10.5	7.9	7.8
10/19/82	1150	0.44	59	3900	13.2	8.4	11.0
11/04/82	1050	0.37	59	4000	10.2	8.9	8.0
11/16/82	1240	E0.50	76	3900	11.1	8.7	9.0
12/02/82	1100	0.46	247	3900	8.0	8.7	8.6
12/29/82	1200	0.30	95	4100	6.0	8.7	10.2
01/06/83	1010	0.27	78	4100	4.0	8.6	15.0
01/19/83	1100	0.17	126	4000	5.0	8.4	14.6
02/04/83	1100	0.22	96	4100	6.0	8.7	9.0
02/16/83	0900	E0.21	156	3100	6.5	8.5	11.1
02/22/83	1200	E7.7	—	3700	2.0	8.5	11.2
02/22/83	1315	8.4	544	—	—	—	—
03/08/83	1000	4.0	1650	3800	5.0	8.4	10.1
03/21/83	1030	6.0	3250	3900	3.0	8.2	11.0
04/06/83	1015	2.0	2280	4100	8.0	8.3	9.2
04/19/83	0915	4.6	2340	4000	11.0	8.2	8.4
04/28/83	1230	6.8	2420	3800	11.0	8.2	9.2
05/04/83	1015	7.6	3010	3600	11.0	8.1	9.2
05/16/83	1020	17	7640	3100	10.0	8.2	9.5
05/24/83	1045	20	9560	3000	17.5	8.3	7.6
06/03/83	0930	73	57500	1550	12.0	8.1	9.0
06/10/83	0845	61	18800	1700	11.5	7.0	8.8
06/16/83	0845	34	9910	1910	11.5	8.2	8.4
06/28/83	1000	27	7070	2460	16.0	7.4	7.6
07/10/83	0730	13	1880	2770	13.0	7.6	7.8
07/18/83	1140	4.5	985	3180	22.5	8.2	6.8
07/28/83	0850	22	18200	1750	15.0	8.3	7.9
08/03/83	0815	16	52900	2080	13.5	7.7	7.6
08/08/83	1000	6.0	1640	2710	17.5	8.1	7.3
08/26/83	0945	4.2	234	3540	16.0	7.6	—
09/08/83	1300	2.1	332	3900	19.0	7.7	—
09/15/83	0930	1.2	83	3510	14.0	7.9	8.6
09/28/83	1045	3.4	2350	3530	10.0	8.3	10.0

E = estimated value



SUSPENDED SEDIMENT DISCHARGE vs STREAMFLOW

EVACUATION CREEK STATION 09306430

NOTE: ONLY DATA COLLECTED DURING STREAMFLOWS GREATER THAN 1 cfs ARE PLOTTED.

FIGURE 6.4-7

increases in suspended sediment concentrations. Although no large runoff events (greater than 100 cfs) were sampled in 1983, a substantial portion of the annual suspended sediment load (in tons) would be expected to occur during these storms.

C. Water Quality Field water quality parameters of specific conductance, water temperature, pH, and dissolved oxygen were collected biweekly during 1983. The field values are shown in Table 6.4-2.

The field values of specific conductance ranged from a low of 1,550 umhos/cm on June 3 to a high of 4,100 umhos/cm recorded on 4 separate occasions. These values were well within the range during baseline monitoring (650 umhos/cm to 5,800 umhos/cm). The lower limit of the 95 percent confidence interval (1,889 umhos/cm) established for baseline conditions was exceeded on 3 occasions in 1983. This was not unexpected, however, because 1983 snowmelt-runoff was very high and conductance generally follows an inverse relationship with discharge. The two lowest conductance values (1,550 and 1,700 umhos/cm) were observed during peak snowmelt-runoff in early June. The other low conductance value (1,750 umhos/cm) was detected following a peak flow from thunderstorm runoff.

Water temperatures for Evacuation Creek ranged from 2.0°C to 22.5°C and were well within the baseline range (0.0°C to 33.5°C).

1983 values of pH ranged from 7.0 to 8.9 units, compared to the baseline range of 7.0 to 9.8 pH units. However, the low value of 7.0 exceeded the lower 95 percent confidence limit of 7.2. This low value occurred during peak snowmelt-runoff in June when the discharge was diluted by surface runoff and the percent contribution of high-pH ground water seepage was low.

The dissolved oxygen concentrations for Evacuation Creek ranged from 6.8 mg/l to 15.0 mg/l. Baseline values ranged from 4.6 mg/l to 14.5 mg/l. Two values on January 6 and 19 (14.6 mg/l and 15.0 mg/l) exceeded the baseline maximum. These two anomalous values may be due to instrument error, since these values represent super-saturated conditions and the conditions prevailing at Evacuation Creek do not justify such results (i.e., ground water seepage is normally low in dissolved oxygen and aeration due to photosynthesis by algae would be at a minimum in winter).

A list of water quality data collected at station 6430 during 1983 can be found in Table 6.4-3. The general water quality characteristics of Evacuation Creek have been discussed in previous WRSP reports (VTN 1976 and VTN 1977).

Several of the outliers detected in 1983 data were the result of insufficient baseline sampling or due to a change in the lower limit of detections by the laboratory. Outliers identified in these instances include turbidity; suspended solids; oil and grease; cyanide; sulfide; cadmium; lead; nickel and silver. Excluding these instances, only two high outliers were observed for Evacuation Creek in 1983. An ammonia value of 0.380 mg/l on April 28 exceeded the baseline maximum of 0.150 mg/l and the ortho-phosphorous level of 0.06 mg/l on April 28 was higher than the 95 percent confidence limit of 0.033 mg/l. These values are believed to be due to natural variations in the nutrient loads introduced into the creek. The input of nutrient-laden water from Evacuation Creek was also detected at White River station 6700 during 1983 (Table 6.4-4).

Several outliers below minimum baseline values and/or lower 95 percent confidence limits were also detected during 1983. These parameters included calcium, non-carbonate hardness, and strontium. These were believed due to the high flow conditions of 1983.

TABLE 6.4-3

LABORATORY WATER QUALITY DATA
FOR EVACUATION CREEK STATION 09306430

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PH, FIELD (UNITS)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	TOTAL DISS SOLIDS, RESIDUE @ 180c (MG/L)
10/13/82	1000	80.58	10.5	7.8	7.9	15	0.80	2	—	3900	3090
01/19/83	1100	0.17	5.0	14.6	8.4	—	—	12	126	4000	3440
04/28/83	1230	6.8	11.0	9.2	8.2	5	1600	1770	2420	3800	2910
08/08/83	1000	6.0	17.5	7.3	8.1	—	—	1450	1640	2710	2480
09/28/83	1045	3.4	10.0	10.0	8.3	5	1600	1940	2350	3530	3010

DATE	TIME	TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS, NONCAR. (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	OXYGEN DEMAND, CHEM-ICAL (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)	ORGANIC CARBON, DIS-SOLVED, (MG/L)	PHENOLS TOTAL (UG/L)	AMMONIA DISS (AS N) (MG/L)	AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)
10/13/82	1000	3069	960	519	441	43	1	9.3	2	<0.06	1.0
01/19/83	1100	3272	1017	606	411	—	—	11	—	<0.06	—
04/28/83	1230	2937	876	518	358	90	—	8.0	<1	0.38	1.7
08/08/83	1000	2379	702	360	342	—	—	7.2	—	<0.02	—
09/28/83	1045	2941	851	481	370	100	<1	8.0	<1	0.10	3.3

DATE	TIME	NITRITE DISS (MG/L AS N)	NITRITE PLUS NITRATE DISS (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)	SILICA, DISS (MG/L AS SIO2)	CAL-CIUM, DISS (MG/L)	MAGNE-SIUM, DISS (MG/L)	POTAS-SIUM, DISS (MG/L)	SODIUM, DISS (MG/L)	SODIUM ADSORP-TION RATIO
10/13/82	1000	<0.02	1.0	0.01	<0.01	12	170	130	6.9	650	9.3
01/19/83	1100	<0.06	0.14	—	—	7.6	160	150	6.4	660	9.2
04/28/83	1230	<0.02	1.2	1.6	0.06	11	120	140	5.4	620	9.3
08/08/83	1000	0.05	1.0	—	—	13	100	110	5.2	520	8.7
09/28/83	1045	<0.02	1.0	1.0	—	12	110	140	5.7	620	9.4

TABLE 6.4-3 (continued...)

LABORATORY WATER QUALITY DATA
FOR EVACUATION CREEK STATION 09306430

DATE	TIME	PERCENT SODIUM	SULFATE, DISS (MG/L)	CHLORIDE, DISS (MG/L)	FLUORIDE, DISS (MG/L)	CYANIDE TOTAL (MG/L AS CN)	SULFIDE TOTAL (MG/L AS S)	BORON, DISS (UG/L)	ALUMINUM DISS (UG/L)	ARSENIC DISS (UG/L)	BARIUM, DISS (UG/L)
10/13/82	1000	59	1800	38	0.9	<0.10	<0.50	1700	10	2	<100
01/19/83	1100	58	2000	44	0.9	—	—	1700	—	—	—
04/28/83	1230	60	1800	28	0.7	<0.01	<0.50	880	10	2	<100
08/08/83	1000	61	1400	27	0.7	—	—	740	—	—	—
09/28/83	1045	61	1800	33	0.8	<0.01	<2.5	940	20	1	<100

DATE	TIME	BERYLLIUM, DISS (UG/L)	CADMIUM DISS (UG/L)	CHROMIUM, DISS (UG/L)	COPPER DISS (UG/L)	IRON DISS (UG/L)	LEAD DISS (UG/L)	MANGANESE, DISS (UG/L)	MERCURY DISS (UG/L)	MOLYBDENUM, DISS (UG/L)	NICKEL, DISS (UG/L)
10/13/82	1000	<10.0	<1	<10	12	30	<1	110	0.1	46	4
01/19/83	1100	—	—	—	—	—	—	—	—	—	—
04/28/83	1230	<10.0	<1	10	20	30	<1	10	<0.1	23	<1
08/08/83	1000	—	—	—	—	—	—	—	—	—	—
09/28/83	1045	<10.0	<1	10	4	70	<1	30	<0.1	30	3

DATE	TIME	SELENIUM DISS (UG/L)	SILVER, DISS (UG/L)	STRONTIUM, DISS (UG/L)	VANADIUM, DISS (UG/L)	ZINC, DISS (UG/L)	GROSS ALPHA DISS (UG/L AS U-NAT)	GROSS BETA DISS (PCI/L AS CS-137)	GROSS BETA, DISS (PCI/L AS SR90 /Y90)	GROSS ALPHA DISS (PCI/L AS U-NAT)
10/13/82	1000	2	<1	3100	2.1	20	—	—	—	—
01/19/83	1100	—	—	—	—	—	—	—	—	—
04/28/83	1230	3	<1	3000	1.0	10	<76	<34	<33	<52
08/08/83	1000	—	—	—	—	—	—	—	—	—
09/28/83	1045	2	<1	2800	<1.0	20	<87	<37	<31	<59

TABLE 6.4-4

OUTLIERS DETECTED IN THE
1983 WATER QUALITY DATA COLLECTED
AT EVACUATION CREEK STATION 09306430

	NO. SAMPLES	EXCEEDANCES OF BASELINE MAXIMUM	EXCEEDANCES OF BASELINE MINIMUM	EXCEEDANCES OF 95 PERCENT CONFIDENCE LIMIT
DISSOLVED OXYGEN (MG/L)	31	1	0	1
PH, FIELD (UNITS)	33	0	0	1
SUSPENDED SOLIDS, RESIDUE @ 105 C (MG/L)	5	1	0	0
SPECIFIC CONDUCTANCE FIELD (UMHOS)	33	0	0	1
HARDNESS, NONCAR. (MG/L AS CACO3)	5	0	0	1
OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG	2	1	0	0
AMMONIA DISS (AS N) (MG/L)	5	1	0	1
PHOSPHORUS, ORTHO DISS (AS P) (MG/L)	2	0	0	1
CALCIUM, DISS (MG/L)	5	0	0	1
STRONTIUM, DISS (UG/L)	3	0	1	0

NOTE: ONLY THOSE 1983 PARAMETERS EXCEEDING A BASELINE MAXIMUM, MINIMUM OR A CONFIDENCE LIMIT ARE SHOWN. REMAINING PARAMETERS DID NOT SHOW ANY EXCEEDANCES.

6.4.2.2 Plant Site Wash Completion of the Plant Site retention dam in late summer of 1983 changed hydrologic conditions at station 6602. The effective drainage area of this station has been reduced from 1.36 mi^2 to 0.08 mi^2 due to retention of runoff. Therefore, the current function of this station is to monitor seepage, spillway overflow, and minor flows from local runoff below the dam.

The total runoff during the 1983 water year was 7.3 acre feet, of which only 1.0 acre foot was natural runoff from below the dam. The remaining water was composed of a mixture of natural runoff (from the drainage above the dam site) and water used in construction that had originally collected in the cutoff trench for the retention dam (immediately upstream of the station). The construction contractor attempted to pump this water into the coffer dams upstream of the dam, however the coffer dams allowed the water to seep back into the cutoff trench. After this unsuccessful attempt, the water was pumped into a small unlined pit located between the cut-off trench and the station. The water then percolated out of the pit into the alluvium. The portion of this water that resurfaced and passed the station was recorded. The maximum instantaneous flow during 1983 was 2.3 cfs on March 5. The only period of natural runoff occurred on August 11-12.

No sediment or water quality data were collected in 1983 at station 6602. No valid continuous specific conductance record was collected during 1983 due to very shallow flow depths or siltation of the conductivity probe during each flow event. Field readings of conductivity were made on April 11 for water that had been pumped from the cutoff trench to the unlined pit below the retention dam (3,900 umhos/cm), and for water that was stored in the coffer dam above retention dam (2,200 umhos/cm). These readings are probably fairly representative of the water that had passed station 6602 during February, March and April. No baseline water quality data for station

6602 are available. However, the above conductivity values are considerably greater than a value of 375 umhos/cm at station 6602 on September 29, 1982.

6.4.2.3 Southam Canyon Wash The total runoff from Southam Canyon Wash for the 1983 water year was 33 acre-feet (0.05 cfs). This compares very closely with the 1975-1982 mean annual runoff of 32 acre-feet at this station. Nearly one-half of the 1983 runoff (15 acre-feet) occurred from a heavy rainstorm on August 11. The instantaneous peak flow from this storm, 440 cfs, exceeded the previous peak flow of 392 cfs recorded in 1979.

Continuous specific conductance readings were recorded during several summer runoff events in Southam Canyon Wash and are summarized below: (Note: the record for many of these days was incomplete due to siltation of the probe on the recession of the flow.)

Date	Mean Daily Discharge	Maximum Specific Conductance (umhos/cm)
June 24	0.01	490
July 7	0.09	348
July 25	0.07	310
August 1	0.04	292
August 11	7.6	120

All specific conductance readings were within the range of baseline values observed at this station (33 to 2,100 umhos/cm). Due to the sporadic nature of runoff in Southam Canyon Wash, no water quality or suspended sediment samples were collected in 1983.

6.4.2.4 Asphalt Wash Streamflow records obtained from the USGS indicate that 1983 total runoff in Asphalt Wash, 11 acre-feet, was well below the 1975-1982 average of 174 acre-feet. The only day of notable runoff (6 acre-

feet) occurred on March 5. Localized summer thunderstorms caused only moderate flows in Asphalt Wash during 1983.

The USGS was not able to collect any suspended sediment or water quality data during the year.

6.4.2.5 White River

A. Streamflow The White River drainage can be generally divided into upper and lower basins in terms of sources of streamflow. The upper and lower basins and gauging stations along the main stem of the White River are illustrated in Figure 6.4-8. USGS station 09304800 (White River below Meeker, Colorado) has been selected as the division point between the upper and lower basins. Lindskov and Kimball (1982) further classified the flow from each basin in terms of its magnitude, i.e., high flow versus baseflow. Thus, the flow regime of the White River near the tracts involves four flow classifications. Upper basin baseflow typically occurs during the fall and winter when the upper basin contributes most of the White River's flow. Upper basin high flow typically occurs during early and mid-summer when snowmelt from the higher elevations of the upper basin (e.g., White River National Forest and Flattops Wilderness Area) is contributing most of the flow. Lower basin baseflow typically occurs during the late summer. Although most of the flow during this period originates from the upper basin, the water quality is greatly modified as a result of consumptive use of water by phreatophytes and irrigation usage within the lower basin. Lower basin high flow occurs whenever the lower basin is contributing a large portion of flow, either through snowmelt or thunderstorm runoff.

Hydrographs depicting the flow regimes of the White River at stations 6395 and 6700 are shown in Figure 6.4-9. Upper basin baseflow occurred from

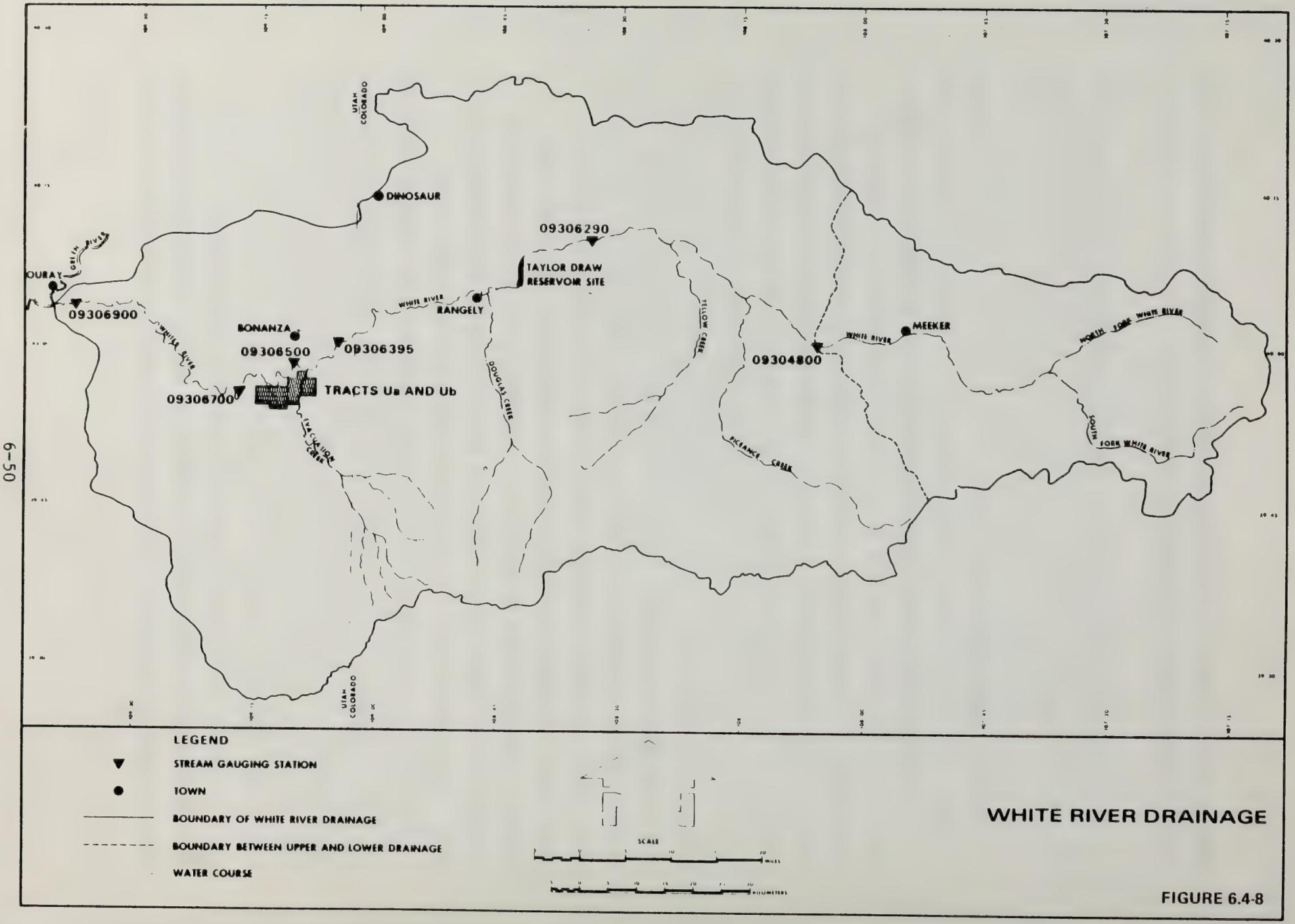
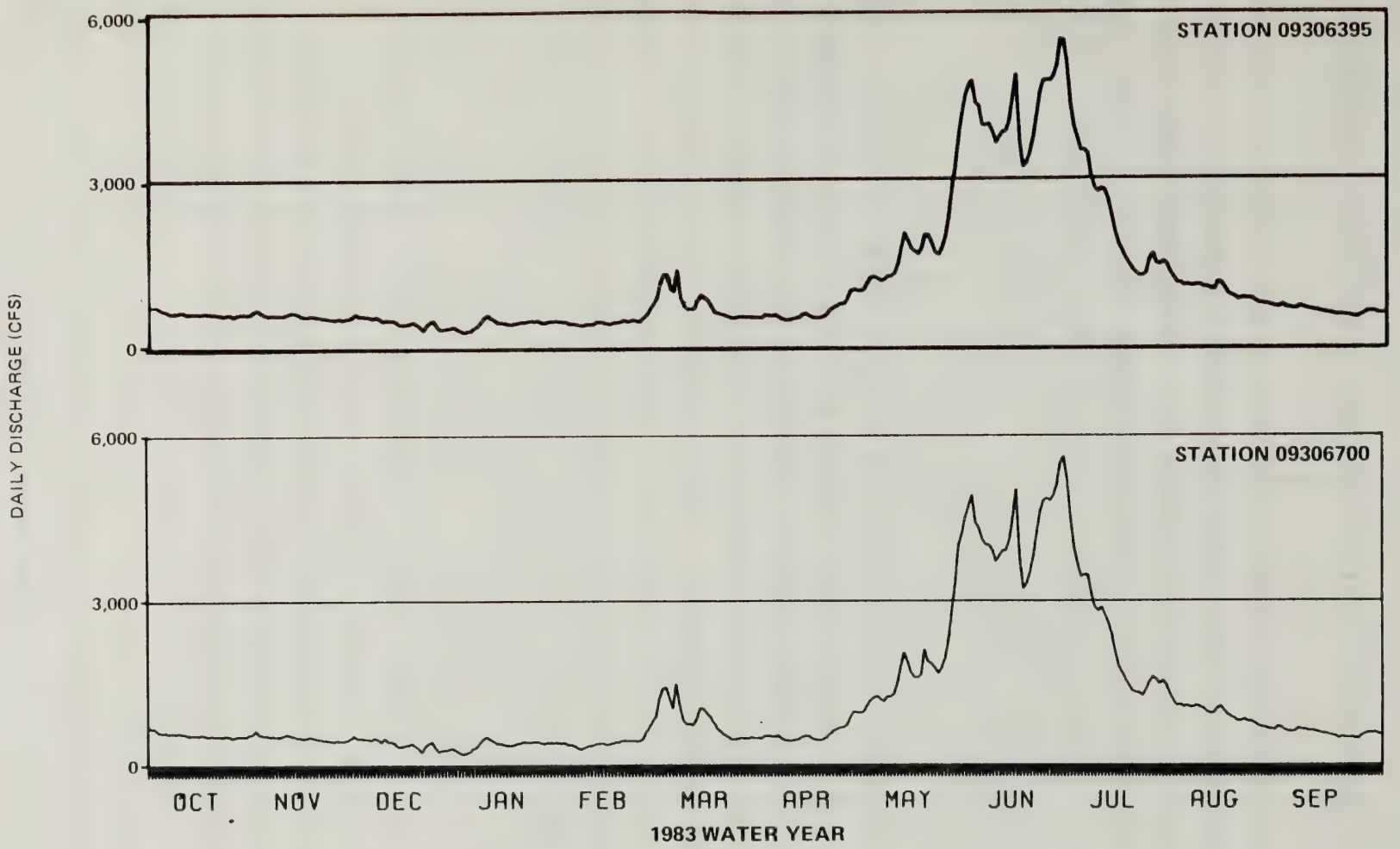

UTAH
COLORADO
DINOSAUR
09306290
TAYLOR DRAW
RESERVOIR SITE
WHITE RIVER
RANGELY
BONANZA
09306500
09306395
09306900
09306700
TRACTS Ua AND Ub
EVACUATION CREEK
DOUGLAS CREEK
YELLOW CREEK
PICEANCE CREEK
09304800
WHITE RIVER
MEEKER
NORTH FORK WHITE RIVER
SOUTH FORK WHITE RIVER
UTAH
COLORADO
LEGEND
STREAM GAUGING STATION
TOWN
BOUNDARY OF WHITE RIVER DRAINAGE
BOUNDARY BETWEEN UPPER AND LOWER DRAINAGE
WATER COURSE
SCALE
WHITE RIVER DRAINAGE

FIGURE 6.4-8



1983 DISCHARGE HYDROGRAPHS FOR
WHITE RIVER STATIONS 6395 and 6700

FIGURE 6.4-9

October 1982 through February 23, 1983. Periods of very low flow during December 1982 and January 1983 corresponded to severe freezing conditions.

On February 24, 1983, flow began to rise rapidly as a result of an early thaw in the lower basin. The rising stage caused a breakup of the river's ice cover. Large sheets of ice jammed at many locations along the river, backing water and ice up over the channel's banks. When the ice jams cleared in a few days, the stage dropped and a large quantity of ice and silt was deposited on the river's flood plain. This period of lower basin high flow (snowmelt) continued through early June.

Upper basin high flow began in late May 1983 and persisted until early August 1983. The unusually high magnitude and long duration of the upper basin high flow period were the result of an extremely heavy snowpack in the mountains. The peak flow during this period exceeded the capacity of the river's banks in certain areas.

The lower basin baseflow period was largely masked during August and September 1983, because of the unusually high level of baseflow from the upper basin.

There were also several days of lower basin high flow during August 1983 that resulted from thunderstorm runoff. These days include August 12, 13, 14 and 31. In addition, Evacuation Creek contributed a notable quantity of thunderstorm runoff on several days. The rise in flow in late July was the result of widespread thunderstorm runoff throughout the upper and lower basins.

A clearer picture of the relative contributions of the upper and lower basins can be seen through comparison of the 1983 records of discharge for

stations 09304800, 6395 and 6700. Monthly and 1983 annual runoff data for the upper and lower basins are shown in Table 6.4-5. It can be seen from these data that the upper basin contributed most (83 percent) of the total runoff passing station 6395 in 1983. Also, the flow contribution from the drainage area between stations 6395 and 6700 (approximately 450 square miles) was an extremely small portion (0.4 percent) of the total runoff passing station 6700 in 1983. The monthly runoff values in this table provide additional information on the flow regimes discussed earlier. For example, the portion of runoff contributed by the lower basin above station 6395 ranged from an average of 34 percent for March - May 1983 (lower basin high flow) to an average of 9 percent for June - July 1983 (upper basin high flow). In addition, it can be seen that there was a net loss of flow for the White River between stations 6395 and 6700 during 6 of 12 months of 1983, despite the contribution of tributaries such as Evacuation Creek. It is believed that these losses occurred primarily because of the consumptive use of water by phreatophytes along this reach. Temporary bank storage and ice formation probably caused noticeable short-term differences between stations; however, losses due to these phenomena tend to be balanced by corresponding gains during the same year. There is, of course, some degree of error associated with the discharge record for a gauging station. The errors in record values also tend to balance over a full year, therefore the annual runoff values for a station are considered to be reliable.

The 1983 annual runoff for station 6395 was 818,862 acre-feet, with a mean annual flow value of 1,131 cfs. Annual runoff for station 6700 was 821,952 acre-feet, with a mean annual flow value of 1,135 cfs. The mean annual flow values for both stations represent the highest values recorded during the period 1975 to the present, and the second highest for the period of record (1924-1979) at station 6500. For example, the 1929 water year had a mean annual flow value of 1,736 cfs at station 6500, which is considerably

TABLE 6.4-5

CONTRIBUTION OF RUNOFF FROM THE UPPER AND LOWER BASINS
OF THE WHITE RIVER DRAINAGE

October 1982 - September 1983

	Runoff in acre-feet		
	Upper Basin[a]	Lower Basin above station 09306395 [b]	Lower Basin between stations 09306395 and 09306700[c]
October 1982	33,171	+ 2,532	- 992
November 1982	28,167	+ 2,994	-1,051
December 1982	23,853	+ 643	- 773
January 1983	19,157	+ 4,903	- 556
February 1983	19,172	+ 5,324	+ 218
March 1983	27,108	+16,436	+5,329
April 1983	25,494	+11,062	-1,010
May 1983	83,716	+41,363	+ 893
June 1983	231,917	+24,867	+1,368
July 1983	120,285	+ 8,881	+ 119
August 1983	43,455	+11,228	- 801
September 1983	27,526	+ 5,608	+ 345
1983 Water Year	683,023	+135,839	+3,090

Notes: (a) Determined from preliminary records for USGS station 09304800.
(b) Determined as the difference between record values for stations 09304800 and 09306395.
(c) Determined as the difference between record values for stations 09306395 and 09306700.

greater than the 1983 mean annual flow or the next highest value of 1,006 cfs for the 1957 water year. The 30-day mean flow values during the period May 31 - June 29, 1983 at stations 6395 and 6700 (4,326 cfs and 4,345 cfs, respectively) represent the highest values observed for the White River (at stations 6395, 6500 or 6700) since 1924. They surpassed the previous maximum 30-day mean flow value of 4,250 cfs at station 6500 during the 1929 water year. The above information makes it clear that the volume of the 1983 snowmelt runoff was an extremely rare occurrence. In contrast, the 1983 maximum instantaneous flows at stations 6395 and 6700 (5,820 cfs on June 28 and 5,620 cfs on June 27 respectively) have a recurrence interval of only 5 to 10 years, based on a log-Pearson type III analysis of the flow record at station 6500 (Linkskov and Kimball 1982). Although the 1983 maximum instantaneous flows were the highest observed during the period 1975 to the present, they do not represent a particularly rare occurrence.

The 1983 minimum daily flows at stations 6395 and 6700 were 220 cfs and 200 cfs on January 2, respectively. Comparison of these values to the low flow frequency analyses for the period of record at station 6500 indicate their recurrence interval is approximately 2 years (Lindskov and Kimball 1982). Thus, the 1983 minimum daily flows for the White River stations 6395 and 6700 were normal in comparison to the long-term records.

B. Suspended Sediment Suspended sediment data collected at White River stations 6395 and 6700 during the 1983 water year are listed in Tables 6.4-6 and 6.4-7. Suspended sediment concentrations ranged from 36 mg/l to 12,330 mg/l at station 6395 and ranged from 78 mg/l to 51,500 mg/l at station 6700. The 1983 maximum suspended sediment concentration of 51,500 mg/l at station 6700 exceeded the baseline maximum of 28,500 mg/l (August 3, 1976) at this station. However, it did not exceed the highest mean daily suspended sediment concentration of 61,000 mg/l recorded at station 6395 (September 8,

TABLE 6.4-6
SUSPENDED SEDIMENT AND FIELD WATER QUALITY DATA
AT WHITE RIVER STATION 09306395

DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	SEDI-MENT, SUS-PENDED (MG/L)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)
10/05/82	1600	625	642	—	—	—	—
10/12/82	1100	610	—	625	8.0	7.9	11.0
10/29/82	1000	625	334	700	4.0	8.1	10.2
11/09/82	1055	549	119	—	—	—	—
11/30/82	1500	518	—	650	0.3	7.3	—
01/20/83	1400	415	110	685	0.0	8.1	11.0
02/03/83	1530	E320	77	—	—	—	—
03/01/83	1630	1030	3978	—	—	—	—
03/10/83	1430	678	950	—	—	—	—
03/22/83	1100	455	343	950	5.0	8.5	10.3
03/24/83	1400	498	319	—	—	—	—
04/07/83	1330	460	317	—	—	—	—
04/20/83	1300	638	1440	—	—	—	—
05/03/83	1530	1180	6030	920	11.0	8.4	8.9
05/18/83	1600	2220	9293	—	—	—	—
05/31/83	1600	4850	12330	—	—	—	—
06/07/83	1100	3910	8027	530	12.0	8.3	8.5
06/23/83	1700	4890	2982	—	—	—	—
07/19/83	1530	1290	1293	—	—	—	—
08/30/83	1100	664	726	700	21.0	8.5	7.6
09/06/83	1330	620	—	770	20.0	8.4	7.5
09/21/83	1500	433	36	—	—	—	—
09/29/83	1145	517	154	—	—	—	—

TABLE 6.4-7
SUSPENDED SEDIMENT AND FIELD WATER QUALITY DATA
AT WHITE RIVER STATION 09306700

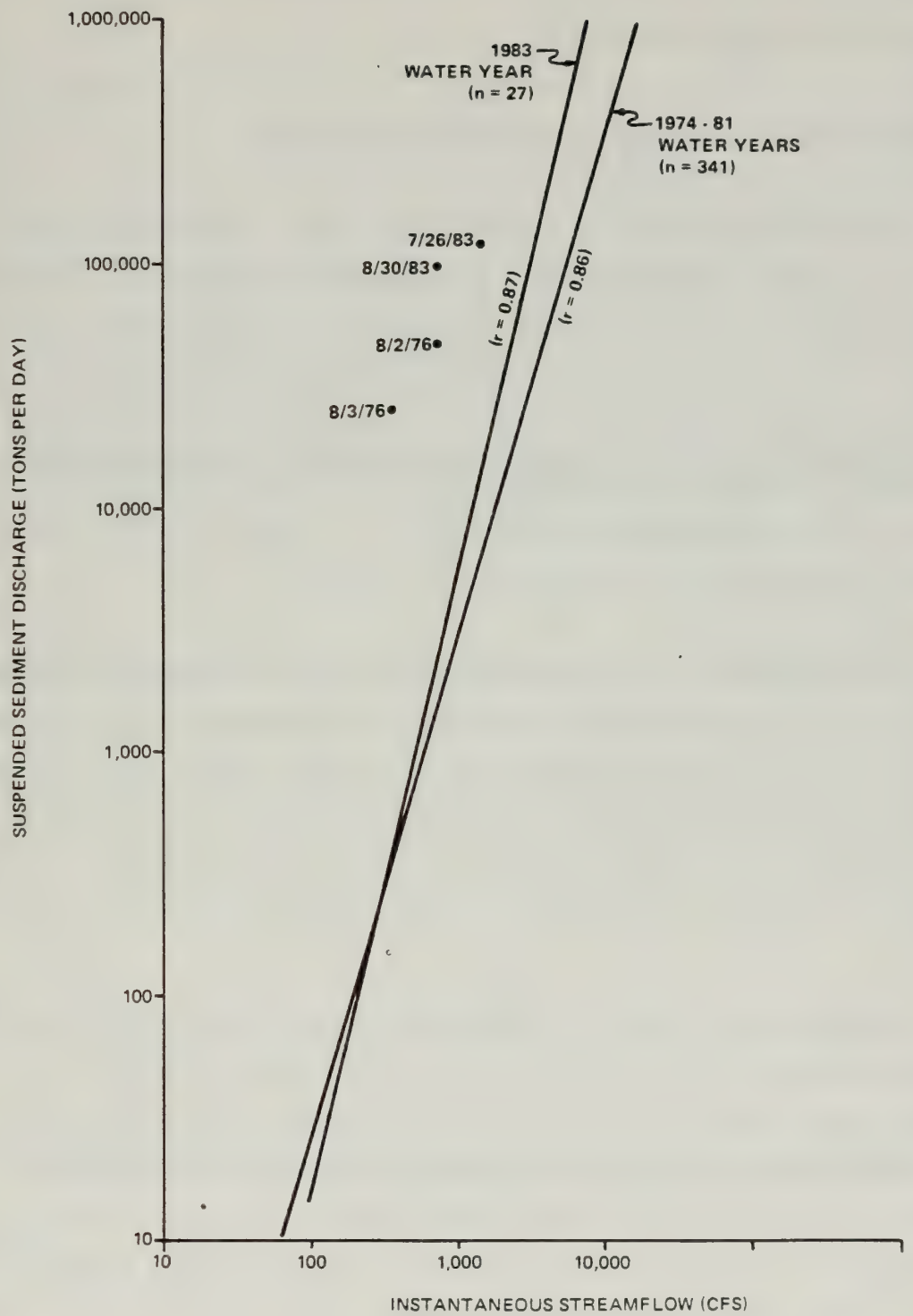
DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	SEDI-MENT, SUS-PENDED (MG/L)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	WATER TEMPER-ATURE (DEG C)	PH FIELD (UNITS)	DIS-SOLVED OXYGEN (MG/L)
10/08/82	1000	E520	—	700	8.5	8.4	9.4
10/08/82	1245	594	916	—	—	—	—
10/12/82	1000	546	—	710	6.8	8.2	10.0
10/18/82	1215	530	636	700	10.0	8.3	9.4
11/01/82	1045	E510	—	700	5.2	8.5	10.2
11/01/82	1240	565	595	—	—	—	—
11/15/82	1000	498	687	720	0.0	8.6	11.6
12/01/82	1000	567	866	690	0.0	8.7	11.2
12/14/82	1130	321	78	—	—	8.6	11.8
01/04/83	1300	242	108	998	0.0	8.6	—
01/20/83	1045	E686	—	690	0.0	8.1	8.6
02/01/83	1315	410	90	—	0.0	8.1	11.6
02/15/83	1300	393	94	720	0.0	8.3	11.4
03/04/83	0935	E1450	—	695	0.0	8.4	9.6
03/04/83	1240	1310	5630	—	—	—	—
03/22/83	1000	472	971	1010	4.8	8.4	10.2
04/07/83	1200	425	590	1030	5.0	8.5	10.2
04/18/83	0920	449	327	940	9.5	8.5	9.7
05/02/83	0945	1170	5220	905	9.0	8.5	9.2
05/13/83	1100	1890	8140	710	9.6	8.4	10.1
05/19/83	0915	1840	11300	920	8.0	—	9.5
05/25/83	0900	2380	10500	850	16.0	—	7.6
06/01/83	1130	4870	10700	650	13.0	—	8.2
06/07/83	1145	4080	7230	540	13.5	7.8	8.4
06/09/83	0920	3840	6390	550	13.0	8.0	—
06/17/83	1130	3270	3680	508	14.3	8.0	8.0
07/07/83	0915	2950	1900	390	17.5	7.8	7.4
07/26/83	0900	E1651	—	650	19.5	7.1	6.4
07/26/83	1125	1483	28100	—	—	—	—
08/01/83	0840	1120	8940	760	20.0	8.5	6.8
08/15/83	0930	885	2480	689	22.0	8.3	6.8
08/30/83	1215	740	51500	1250	19.0	8.2	—
09/06/83	0930	673	3160	976	17.7	7.8	—

1978) during the baseline period. Both the 1978 and the 1983 maximum suspended sediment values were caused by sediment contributions from lower basin tributaries above each station. In 1978, the Yellow Creek drainage had a peak flow event shortly before station 6395 was sampled. Similarly, in 1983 (August 30) Evacuation Creek had a peak flow of 543 cfs about 8 hours before station 6700 was sampled. Flows of this magnitude from Evacuation Creek, which are not a particularly unusual occurrence, have had suspended sediment concentrations well over 100,000 mg/l. Thus, the suspended sediment concentration for the White River on August 30, 1983 reflected this heavy influx of sediment.

The 1983 White River suspended sediment rating curve is plotted in Figure 6.4-10. This figure also provides a comparison to the composite suspended sediment rating curve for the baseline years (1974-1981). The 1983 curve is slightly steeper than the baseline curve, indicating an increased suspended sediment transport rate during 1983. However, the upper end of the 1983 curve is biased by two outliers which resulted from tributary inflows shortly before sampling. As shown in this figure, similar outliers have been detected in previous years, also.

Based on these observations, it is concluded that project-related activities did not have an impact on the sediment transport characteristics of the White River. Observed differences between 1983 data and baseline records are attributed to the hydrologic system's response to natural variations in climatic conditions.

C. Water Quality Water quality data collected at White River stations 6395 and 6700 during 1983 included continuous (daily) water temperature and specific conductance records, field water quality data, and laboratory water quality data. The following discussion presents the 1983 data under these



SUSPENDED SEDIMENT DISCHARGE vs STREAMFLOW

WHITE RIVER STATION 09306700

FIGURE 6.4-10

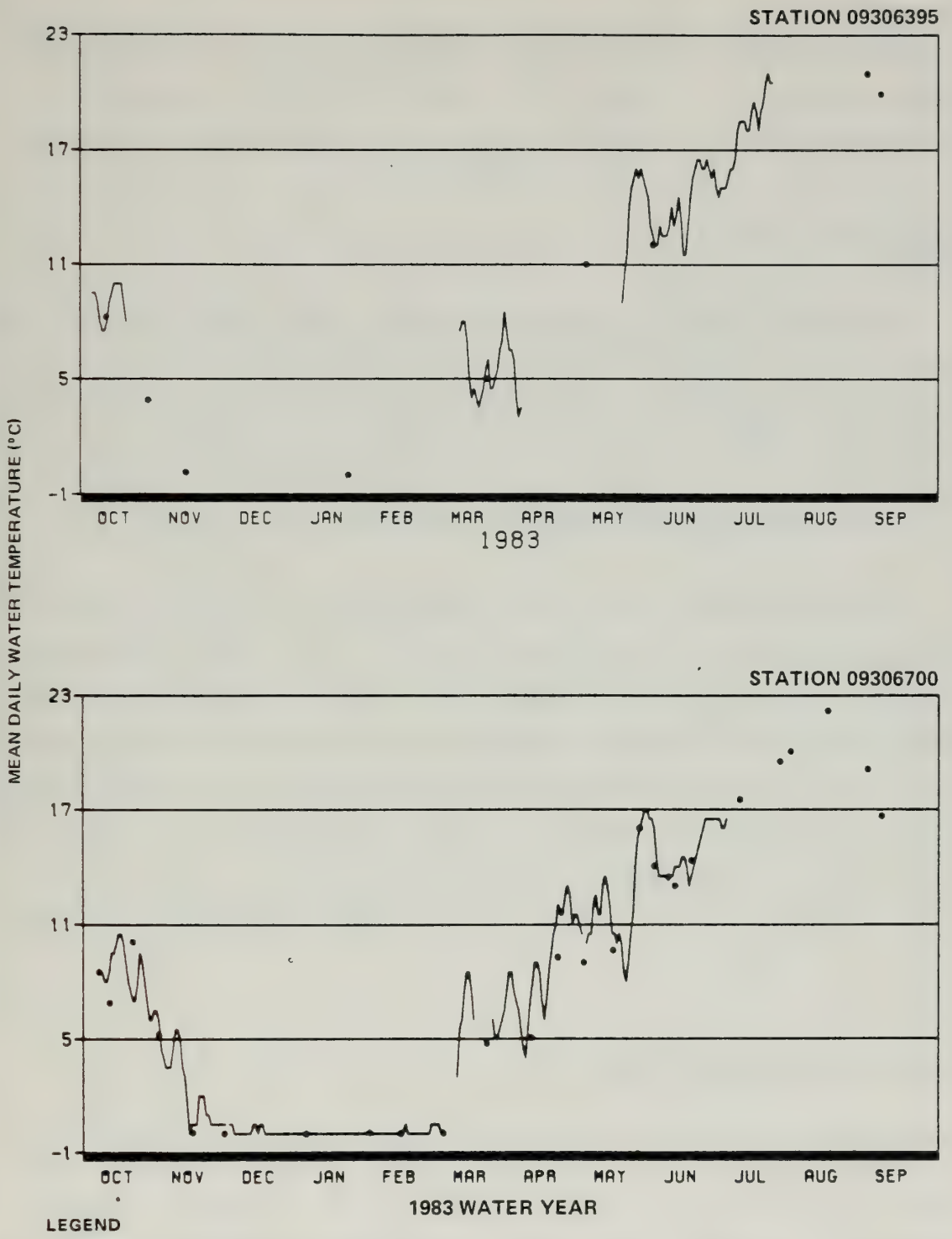
three general topics, followed by assessments of outliers detected in 1983 and an interstation comparison.

Water Temperature and Specific Conductance Records

The 1983 mean daily and instantaneous water temperature values (during station visits) recorded at White River stations 6395 and 6700 are shown in Figure 6.4-11. Mean daily water temperatures at station 6700 ranged from 0.0 to 17.0°C during the year. No valid daily temperature records were obtained for July through September, due primarily to siltation of the probe. However, instantaneous measurements for this period ranged from 17.5 to 22.0°C. All 1983 temperature observations at station 6700 were below the baseline maximum mean daily temperature (26.0°C).

The mean daily temperature values at station 6395 ranged from 3.0 to 21.0°C. All temperature data were below the maximum mean daily temperature (28.5°C) for the baseline period. As in previous years, water temperatures at both White River stations exhibited a pattern directly related to air temperature with an approximate 1 or 2 day lag period (Lindskov and Kimball 1982).

The mean daily specific conductance values at station 6700 ranged from 370 micromhos/cm to 1,060 micromhos/cm. Mean values were within the range of baseline mean daily values (238 to 1,400 micromhos/cm) and below the upper 99 percent confidence limit for the baseline values (1,140 micromhos/cm). At station 6395, mean daily specific conductance values ranged from 337 to 1,020 micromhos/cm. Minimum values at both White River stations occurred during peak snowmelt from the upper basin (June), while maximum values occurred primarily during early spring snowmelt from the lower basin (March). Hydrographs of specific conductance for stations 6395 and 6700, including both



1983 WATER TEMPERATURE HYDROGRAPHS
FOR WHITE RIVER STATIONS

FIGURE 6.4-11

mean daily specific conductance and instantaneous values (during station visits), are shown in Figure 6.4-12. The 1983 specific conductance fluctuations closely followed previously established baseline patterns.

Field Water Quality Data

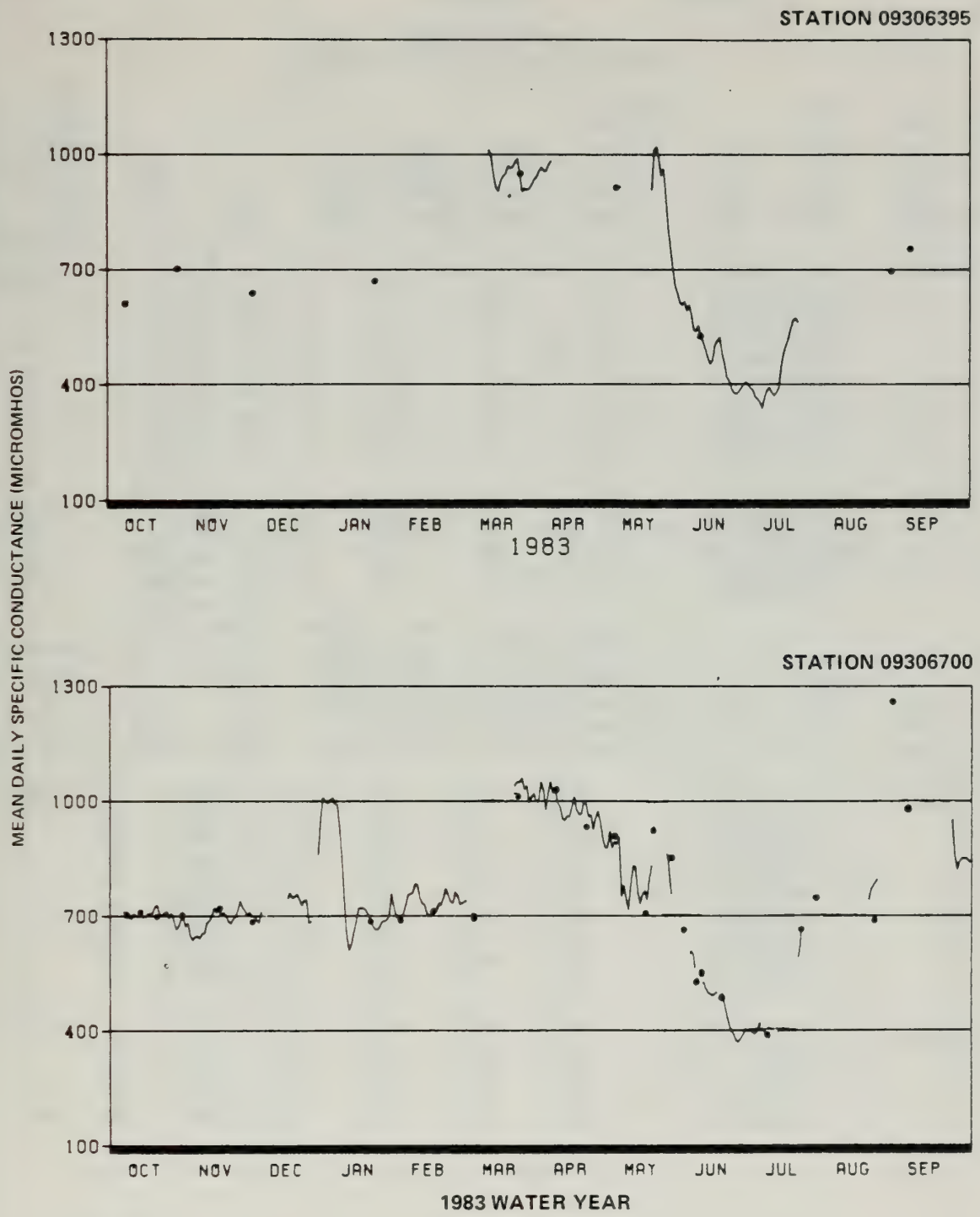
Field water quality parameters measured at White River stations 6395 and 6700 in 1983 are listed in Tables 6.4-6 and 6.4-7, respectively. Field values of pH ranged from 7.3 to 8.5 at station 6395 and ranged from 7.1 to 8.7 at station 6700. These values were within the baseline ranges and 95 percent confidence limits of pH for each station.

Dissolved oxygen concentrations ranged from 7.5 to 11.0 at station 6395 and from 6.4 mg/l to 11.8 mg/l at station 6700. All values were within the baseline ranges for dissolved oxygen. One dissolved oxygen reading of 11.8 mg/l (December 14) at station 6700 did exceed the upper 95 percent confidence limit. This value was believed to be a natural variation, because values of this magnitude have been measured previously when water temperatures were near 0.0°C. As reported previously, the dissolved oxygen concentration varies inversely with the temperature of the water (Lindskov and Kimball, 1982).

Laboratory Water Quality Data

The laboratory water quality data collected in 1983 for White River stations 6395 and 6700 are listed in Table 6.4-8. Changes in chemical composition of the White River under varying flow regimes have been described in previous WRSP reports (VTN 1976 and VTN 1977).

A comparison of the 1983 major ion distribution and the typical baseline



1983 SPECIFIC CONDUCTANCE HYDROGRAPHS
FOR WHITE RIVER STATIONS

FIGURE 6.4-12

TABLE 6.4-8

WATER QUALITY DATA
FOR WHITE RIVER STATIONS 09306395 AND 09306700

STATION NUMBER	DATE	TIME	STREAM FLOW, INSTAN-TANEOUS (CFS)	WATER TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PH, FIELD (UNITS)	COLOR (PCU)	TURBI-DITY (NTU)	SUS-PENDED SOLIDS, RESIDUE @ 105 C (MG/L)	SEDI-MENT, SUS-PENDED (MG/L)
09306395	10/12/82	1100	610	8.0	11.0	7.9	10	39	157	—
	10/29/82	1000	625	4.0	10.2	8.1	—	—	—	334
	11/30/82	1500	518	0.3	—	7.3	—	—	—	—
	01/20/83	1400	415	0.0	11.0	8.1	—	—	45	110
	03/22/83	1100	455	5.0	10.3	8.5	—	—	218	343
	05/03/83	1530	1180	11.0	8.9	8.4	—	—	—	—
	06/07/83	1100	3910	12.0	8.5	8.3	5	1700	928	—
	08/30/83	1100	664	21.0	7.6	8.5	5	320	573	726
	09/06/83	1330	620	20.0	7.5	8.4	—	—	—	—
09306700	10/12/82	1000	546	6.8	10.0	8.2	15	110	58	—
	01/20/83	1045	E430	0.0	8.6	8.1	—	—	43	—
	03/22/83	1000	472	4.8	10.2	8.4	—	—	508	971
	06/07/83	1145	4080	13.5	8.4	7.8	10	2300	136	7230
	08/30/83	1215	740	19.0	—	8.2	35	23000	34900	51500

STATION NUMBER	DATE	TIME	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	TOTAL DISS SOLIDS, RESIDUE @ 180c (MG/L)	TOTAL DISS. SOLIDS, SOLIDS, CALC. SUM (MG/L)	HARD-NESS TOTAL (MG/L AS CACO3)	HARD-NESS, NONCAR. (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	OXYGEN DEMAND, CHEM-ICAL (MG/L)	OIL AND GREASE, TOTAL RECOV. GRAVIM. (MG/L)
09306395	10/12/82	1100	625	434	439	254	73	181	21	<1
	10/29/82	1000	700	—	422	249	74	175	—	—
	11/30/82	1500	650	—	447	261	78	183	—	—
	01/20/83	1400	685	421	409	241	66	175	—	—
	03/22/83	1100	950	625	621	325	98	227	—	—
	05/03/83	1530	920	—	610	316	103	213	—	—
	06/07/83	1100	530	335	332	200	44	156	170	<1
	08/30/83	1100	700	441	457	275	82	193	42	<1
	09/06/83	1330	770	—	509	300	86	214	—	—
09306700	10/12/82	1000	710	435	428	251	69	182	33	<1
	01/20/83	1045	690	460	423	258	79	179	—	—
	03/22/83	1000	1010	654	658	335	107	228	—	—
	06/07/83	1145	540	368	371	223	68	155	130	<1
	08/30/83	1215	1250	882	872	324	148	176	1400	<1

TABLE 6.4-8 (continued...)

WATER QUALITY DATA
FOR WHITE RIVER STATIONS 09306395 AND 09306700

STATION NUMBER	DATE	TIME	ORGANIC CARBON, DIS-SOLVED, (MG/L)	PHENOLS TOTAL (UG/L)	AMMONIA DISS (AS N) (MG/L)	AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)	NITRITE DISS (MG/L AS N)	NITRITE PLUS NITRATE DISS (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, ORTHO DISS (AS P) (MG/L)
09306395	10/12/82	1100	3.4	<1	0.08	45	<0.02	<0.10	0.08	<0.01
	10/29/82	1000	—	—	—	—	—	<0.10	—	<0.01
	11/30/82	1500	—	—	—	—	—	<0.10	—	<0.01
	01/20/83	1400	3.7	—	0.06	—	<0.02	0.22	—	0.02
	03/22/83	1100	5.4	—	0.22	—	<0.02	0.14	—	0.06
	05/03/83	1530	—	—	—	—	—	0.81	—	0.02
	06/07/83	1100	6.1	7	<0.06	1.0	<0.02	0.75	0.43	0.03
	08/30/83	1100	4.2	4	0.04	1.2	<0.02	0.25	0.02	0.04
	09/06/83	1330	—	—	—	—	—	0.39	—	0.03
09306700	10/12/82	1000	2.7	5	<0.06	1.0	<0.02	<0.10	0.30	<0.01
	01/20/83	1045	2.5	—	<0.06	—	<0.06	0.12	—	-
	03/22/83	1000	4.9	—	0.11	—	<0.02	0.15	—	-
	06/07/83	1145	6.8	4	0.14	3.3	<0.02	0.83	1.4	0.02
	08/30/83	1215	11	13	0.07	47	<0.02	1.0	23	0.01

STATION NUMBER	DATE	TIME	SILICA, DISS (MG/L AS SIO2)	CAL-CIUM, DISS (MG/L)	MAGNE-SIUM, DISS (MG/L)	POTAS-SIUM, DISS (MG/L)	SODIUM, DISS (MG/L)	SODIUM ADSORP-TION RATIO	PERCENT SODIUM	SUL-FATE, DISS (MG/L)
09306395	10/12/82	1100	14	62	24	1.5	47	1.3	29	160
	10/29/82	1000	14	62	23	1.4	45	1.3	28	150
	11/30/82	1500	14	65	24	1.3	48	1.3	28	160
	01/20/83	1400	14	62	21	1.4	40	1.2	26	150
	03/22/83	1100	13	71	36	2.3	87	2.2	37	240
	05/03/83	1530	11	64	38	2.5	87	2.2	37	260
	06/07/83	1100	11	44	22	1.4	33	1.0	26	120
	08/30/83	1100	14	64	28	1.7	49	1.3	28	170
	09/06/83	1330	16	69	31	2.2	58	1.5	29	190
09306700	10/12/82	1000	14	61	24	1.4	48	1.4	29	150
	01/20/83	1045	15	67	22	1.6	42	1.2	26	150
	03/22/83	1000	13	75	36	2.5	96	2.3	38	270
	06/07/83	1145	12	48	25	2.0	41	1.2	28	140
	08/30/83	1215	10	67	38	4.1	160	4.0	51	470

TABLE 6.4-8 (continued...)

WATER QUALITY DATA
FOR WHITE RIVER STATIONS 09306395 AND 09306700

STATION NUMBER	DATE	TIME	CHLORIDE, DISS (MG/L)	FLUORIDE, DISS (MG/L)	CYANIDE TOTAL (MG/L AS CN)	SULFIDE TOTAL (MG/L AS S)	BORON, DISS (UG/L)	ALUMINUM DISS (UG/L)	ARSENIC DISS (UG/L)	BARIUM, DISS (UG/L)
09306395	10/12/82	1100	21	0.2	<0.01	<0.50	50	20	1	43
	10/29/82	1000	21	0.3	—	—	40	—	—	—
	11/30/82	1500	24	0.3	—	—	40	—	—	—
	01/20/83	1400	15	0.3	—	—	50	—	—	—
	03/22/83	1100	35	0.3	—	—	60	—	—	—
	05/03/83	1530	20	0.3	—	—	100	—	—	—
	06/07/83	1100	7.3	0.3	<0.01	<2.5	80	60	1	240
	08/30/83	1100	14	0.2	<0.01	<0.50	60	30	2	59
	09/06/83	1330	14	0.3	—	—	70	—	—	—
09306700	10/12/82	1000	20	0.3	<0.10	<0.50	50	20	1	43
	01/20/83	1045	18	0.3	—	—	40	—	—	—
	03/22/83	1000	29	0.3	—	—	80	—	—	—
	06/07/83	1145	10	0.2	<0.01	<2.5	50	20	1	35
	08/30/83	1215	19	0.6	<0.01	<5.0	130	20	1	63

STATION NUMBER	DATE	TIME	BERYLLIUM, DISS (UG/L)	CADMIUM DISS (UG/L)	CHROMIUM, DISS (UG/L)	COPPER DISS (UG/L)	IRON DISS (UG/L)	LEAD DISS (UG/L)	MANGANESE, DISS (UG/L)	MERCURY DISS (UG/L)
09306395	10/12/82	1100	<1.0	<1	<10	10	34	2	3	<0.1
	10/29/82	1000	—	—	—	—	—	—	—	—
	11/30/82	1500	—	—	—	—	—	—	—	—
	01/20/83	1400	—	—	—	—	—	—	—	—
	03/22/83	1100	—	—	—	—	—	—	—	—
	05/03/83	1530	—	—	—	—	—	—	—	—
	06/07/83	1100	<1.0	<1	<10	10	57	5	8	<0.1
	08/30/83	1100	1.0	<1	<10	10	40	4	1	<0.1
	09/06/83	1330	—	—	—	—	—	—	—	—
09306700	10/12/82	1000	<0.5	<1	10	45	20	<1	4	0.1
	01/20/83	1045	—	—	—	—	—	—	—	—
	03/22/83	1000	—	—	—	—	—	—	—	—
	06/07/83	1145	<1.0	<1	<10	10	6	2	4	<0.1
	08/30/83	1215	<0.5	<1	<10	12	17	<1	2	<0.1

TABLE 6.4-8 (continued...)

WATER QUALITY DATA
FOR WHITE RIVER STATIONS 09306395 AND 09306700

STATION NUMBER	DATE	TIME	MOLYB-DENUM, DISS (UG/L)	NICKEL, DISS (UG/L)	SELE-NIUM DISS (UG/L)	SILVER, DISS (UG/L)	STRON-TIUM, DISS (UG/L)	VANA-DIUM, DISS (UG/L)	ZINC, DISS (UG/L)	GROSS ALPHA DISS (UG/L AS U-NAT)
09306395	10/12/82	1100	1	<1	2	1	740	<1.0	12	—
	10/29/82	1000	—	—	—	—	—	—	—	—
	11/30/82	1500	—	—	—	—	—	—	—	—
	01/20/83	1400	—	—	—	—	—	—	—	—
	03/22/83	1100	—	—	—	—	—	—	—	—
	05/03/83	1530	—	—	—	—	—	—	—	—
	06/07/83	1100	6	2	2	<1	440	3.4	190	<9.6
	08/30/83	1100	3	3	2	<1	790	2.8	73	<11
	09/06/83	1330	—	—	—	—	—	—	—	—
09306700	10/12/82	1000	3	1	1	<1	750	<1.0	17	—
	01/20/83	1045	—	—	—	—	—	—	—	—
	03/22/83	1000	—	—	—	—	—	—	—	—
	06/07/83	1145	7	2	<1	<1	520	8.0	14	<11
	08/30/83	1215	8	5	2	<1	1100	1.6	11	<26

STATION NUMBER	DATE	TIME	GROSS BETA DISS (PCI/L AS CS-137)	GROSS BETA, DISS (PCI/L AS SR90 /Y90)	GROSS ALPHA DISS (PCI/L AS U-NAT)
09306395	10/12/82	1100	—	—	—
	10/29/82	1000	—	—	—
	11/30/82	1500	—	—	—
	01/20/83	1400	—	—	—
	03/22/83	1100	—	—	—
	05/03/83	1530	—	—	—
	06/07/83	1100	<4.1	<4.0	<6.5
	08/30/83	1100	6.5	6.2	<7.5
	09/06/83	1330	—	—	—
09306700	10/12/82	1000	—	—	—
	01/20/83	1045	—	—	—
	03/22/83	1000	—	—	—
	06/07/83	1145	<4.3	<4.1	<7.4
	08/30/83	1215	<12	<11	<17.6

ion distribution for different flow regimes is shown in Figure 6.4-13. Three of the regimes are represented by water quality samples collected during 1983.

The January 20 sample at station 6395 was representative of upper basin baseflow. The water quality was typified by increased TDS levels and high proportions of calcium and bicarbonate (alkalinity).

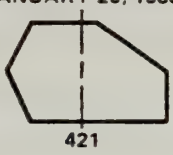
The March 22 sample collected at station 6395 was high in sodium and sulfate salts and was typical of lower basin high flow. Some upper basin contribution was also occurring, as represented by the relatively high proportions of calcium and bicarbonate. The samples collected on May 3 at station 6395 and on March 22 at station 6700 have similar distributions to this sample.

The major ion distribution shown for the June 7 sample collected at station 6395 represented snowmelt runoff conditions. This distribution, typical of upper basin high flow, was relatively low in TDS with calcium and bicarbonate as the dominant ions. The June 7 sample shown for station 6395 was similar to the June 7 sample collected at station 6700.

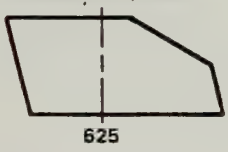
A sample typifying lower basin baseflow was not obtained during the 1983 water year. This was the result of higher than normal baseflows during late summer. The two samples collected on August 30 illustrate the effect of a lower basin tributary flood event on the water quality of the White River. Evacuation Creek station 6430 recorded a peak flow early on August 30 as a result of localized thunderstorms. Station 6395 displayed characteristics of a typical upper basin baseflow regime on this date. However, as a result of the influx of flood waters from Evacuation Creek, station 6700 showed characteristics typical of lower basin high flow. This tributary inflow

STATION NO. 09306395
1983 WATER YEAR

UPPER BASIN BASEFLOW
JANUARY 20, 1983

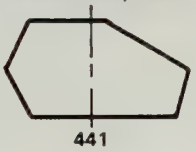


LOWER BASIN HIGHFLOW
MARCH 22, 1983

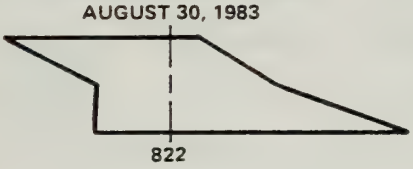


UPPER BASIN HIGHFLOW
JUNE 7, 1983

UPPER BASIN BASEFLOW
AUGUST 30, 1983



STATION NO. 09306700
LOWER BASIN HIGHFLOW
AUGUST 30, 1983



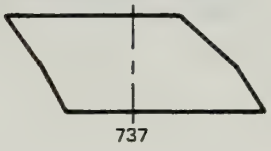
WHITE RIVER STATION NOS.
09306395 THROUGH 09306900
1975 – 1979 WATER YEARS

UPPER BASIN BASEFLOW

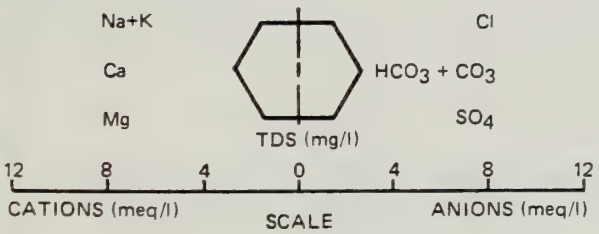
LOWER BASIN HIGHFLOW

UPPER BASIN HIGHFLOW

LOWER BASIN BASEFLOW



LEGEND



DISTRIBUTION OF MAJOR IONS
DURING DIFFERENT FLOW
REGIMES AT WHITE RIVER

FIGURE 6.4-13

resulted in high levels of TDS and many other chemical constituents at station 6700. It should be noted here that the occurrence of this Evacuation Creek inflow is not at all unusual. Many others of similar magnitude have occurred since gauging records began at station 6430 in October 1974. However, the August 30, 1983 sample at station 6700 was the first sample ever collected at this station near the peak resulting from such a tributary inflow.

Water Quality Outliers Detected in 1983

Water quality data for the White River stations during 1983 showed several parameters outside the range of baseline values. These values, plus any parameters that exceeded the 95 percent confidence limits (of baseline), were considered "outliers" and are discussed below.

The results of the statistical tests performed on 1983 data at station 6700 are shown in Table 6.4-9. High levels of suspended solids were detected during the 1983 water year. A value of 34,900 mg/l was observed at station 6700 on August 30. The maximum baseline value reported for this station was 380 mg/l. This anomaly is believed to be partially due to the small sample size, since only five previous determinations were made at this station. (Suspended solids analyses were not performed during early baseline years.) In addition, a localized storm on the morning of August 30, caused a peak flow in Evacuation Creek. The suspended solids transported by such flows are very high and probably contributed a sudden influx of suspended matter into the White River.

The chemical oxygen demand (COD) also showed valued exceeding those reported during baseline monitoring. The maximum COD value of 1,400 mg/l occurred on August 30 at station 6700. The COD concentration at station 6395

TABLE 6.4-9

OUTLIERS DETECTED IN THE
1983 WATER QUALITY DATA COLLECTED
AT WHITE RIVER STATION 09306700

	NO. SAMPLES	EXCEEDANCES OF BASELINE MAXIMUM	EXCEEDANCES OF BASELINE MINIMUM	EXCEEDANCES OF 95 PERCENT CONFIDENCE LIMIT
DISSOLVED OXYGEN (MG/L)	25	0	0	1
SUSPENDED SOLIDS, RESIDUE @ 105 C (MG/L)	5	1	0	-
SEDIMENT, SUSPENDED (MG/L)	27	3	0	8
SPECIFIC CONDUCTANCE FIELD (UMHOS)	27	0	0	1
TOTAL DISS SOLIDS, RESIDUE @ 180c (MG/L)	5	0	0	1
TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	5	1	0	1
HARDNESS, NONCAR. (MG/L AS CACO3)	5	0	0	1
OXYGEN DEMAND, CHEMICAL (MG/L)	3	2	0	2
PHENOLS TOTAL (UG/L)	3	0	0	1
AMMONIA DISS (AS N) (MG/L)	5	0	0	2
AMMONIA + ORG. NITRO. TOTAL (MG/L AS N)	3	1	0	2
NITRITE PLUS NITRATE DISS (MG/L AS N)	5	2	0	2
PHOSPHORUS, TOTAL (MG/L AS P)	3	1	0	1
SODIUM, DISS (MG/L)	5	0	0	1
SODIUM ADSORPTION RATIO	5	0	0	1
PERCENT SODIUM	5	0	0	1
SULFATE, DISS (MG/L)	5	1	0	1
BARIUM, DISS (UG/L)	3	0	1	0
IRON DISS (UG/L)	3	0	1	0
MANGANESE, DISS (UG/L)	3	0	1	1
MOLYBDENUM, DISS (UG/L)	3	0	0	1
NICKEL, DISS (UG/L)	3	0	1	0
VANADIUM, DISS (UG/L)	3	0	0	1

NOTE: ONLY THOSE 1983 PARAMETERS EXCEEDING A BASELINE MAXIMUM, MINIMUM OR A CONFIDENCE LIMIT ARE SHOWN. REMAINING PARAMETERS DID NOT SHOW ANY EXCEEDANCES.

on this date was also high at 42 mg/l. The maximum baseline value reported for either station was 43 mg/l. The high level of COD is probably a result of a natural influx of organic constitutents and other dissolved solids from Evacuation Creek. Naturally occurring organic constituents contributing to the COD could include organic carbon, organic nitrogen, phenols and phosphorous. Other high COD levels of 170 mg/l at station 6395 and 130 mg/l at station 6700 were detected on June 7. This corresponded with the year's highest concentrations of organics such as dissolved organic carbon, phosphorous and phenols. These two COD values for the June 7 samples probably resulted from the unusually high magnitude of snowmelt runoff on that date.

The concentrations of several nitrogen containing compounds exceeded the maximum baseline values. Dissolved ammonia (as N) reached 0.220 mg/l on March 22 at station 6395. Although this exceeded the baseline maximum at this station (0.13 mg/l), the value was not project-related since this station is upstream of the tracts. The maximum total ammonia and organic nitrogen sampled during 1983 was 45 mg/l on October 12 at station 6395 and 47 mg/l on August 30 at station 6700. The baseline maximum for this parameter was 3.8 mg/l. In the August sample, the high ammonia and organic nitrogen concentration probably resulted from tributary inflows (i.e., Evacuation Creek), that carried large quantities of suspended organic materials. Several high values of dissolved nitrite plus nitrate (as N) were observed during the 1983 water year. On June 7, a value of 0.97 mg/l at station 6700 exceeded the baseline maximum of 0.54 mg/l. However, on this same date, the upper station reported a high value of 0.75 mg/l. Also, on May 3 a value of 0.81 mg/l was detected at station 6395. Levels close to baseline maximum were also detected for ammonia, phosphorous, and ammonia and organic nitrogen on June 7. The increase in nitrite plus nitrate and other organics may be due to high levels of snowmelt runoff from areas where livestock had wintered.

The sulfate concentration of 470 mg/l on August 30 at station 6700 exceeded the baseline maximum of 360 mg/l. This exceedance is attributed to the inflow from Evacuation Creek on this date because the upper station did not show any unusual increase in sulfate content. This type of lower basin runoff has characteristically high sodium and sulfate concentrations.

White River Interstation Comparison

Statistical comparison of the continuous records of specific conductance at stations 6395 and 6700 was limited because of the poor recovery of data during 1983. A total of 47 concurrent days of the 1983 records were available for statistical comparison. A paired t-test, comparing the mean values from the concurrent days of record, indicated a significant difference ($P < 0.05$) between stations. However, this difference is considered a natural condition due to inflows of Evacuation Creek. A significant difference has also been found in previous non-construction years (e.g., 1981).

The concurrent water quality samples collected at White River stations 6395 and 6700 during 1983 were compared statistically for significant differences. Normal chemical variations with changing flow regimes dictated that only concurrent (same day) data be compared because concurrent values provide a more representative and unbiased comparison. The small sample size ($n = 5$), dictated that a non-parametric test be used. The statistical test selected, a paired-replicates test, met these requirements and allowed for significant differences between the stations to be determined. Generally, the chemical constituent concentrations at station 6700 were very similar those at station 6395. However, three parameters (specific conductance, total dissolved solids, and dissolved sodium) showed a significant increase ($P < 0.05$) at station 6700. These parameters are closely related to each other; an increase in sodium concentration would cause a corresponding

increase in specific conductance and in total dissolved solids. Closer analysis of the five concurrent sodium values (shown below), indicate only a very slight difference between stations, except for the last data pair.

Sodium Concentration (mg/l)

Date	Station 6395	Station 6700
10/12/82	47	48
1/20/83	40	42
3/22/83	87	96
6/7/83	33	41
8/30/83	49	160

As mentioned previously, a peak flow event in the Evacuation Creek basin occurred on August 30, and the normal contribution of high TDS water from this drainage explains the downstream increases in sodium, TDS, and specific conductance on this date.

The Mann-Whitney U-test, used to compare the median values for station 6395 and station 6700 (determined from the five concurrent samples), showed no significant differences ($P > 0.05$) between stations for all parameters.

In summary, the results of statistical tests for significant differences between White River stations, indicate that no notable project-related water quality impacts occurred between these stations in 1983.

6.4.3 Ground Water

Results and analyses of ground water monitoring program are presented in the order in which the field data program was described in Section 6.3.2, namely Birds Nest Zone, Uinta Formation, Southam Canyon alluvium and reten-

tion dam wells. Discussions of each of these ground water zones are organized under separate water level and water quality sections.

6.4.3.1 Birds Nest Zone

A. Water Levels Water level data are presented herein separately for P-wells and G-wells, followed by a brief summary of findings.

P-Wells

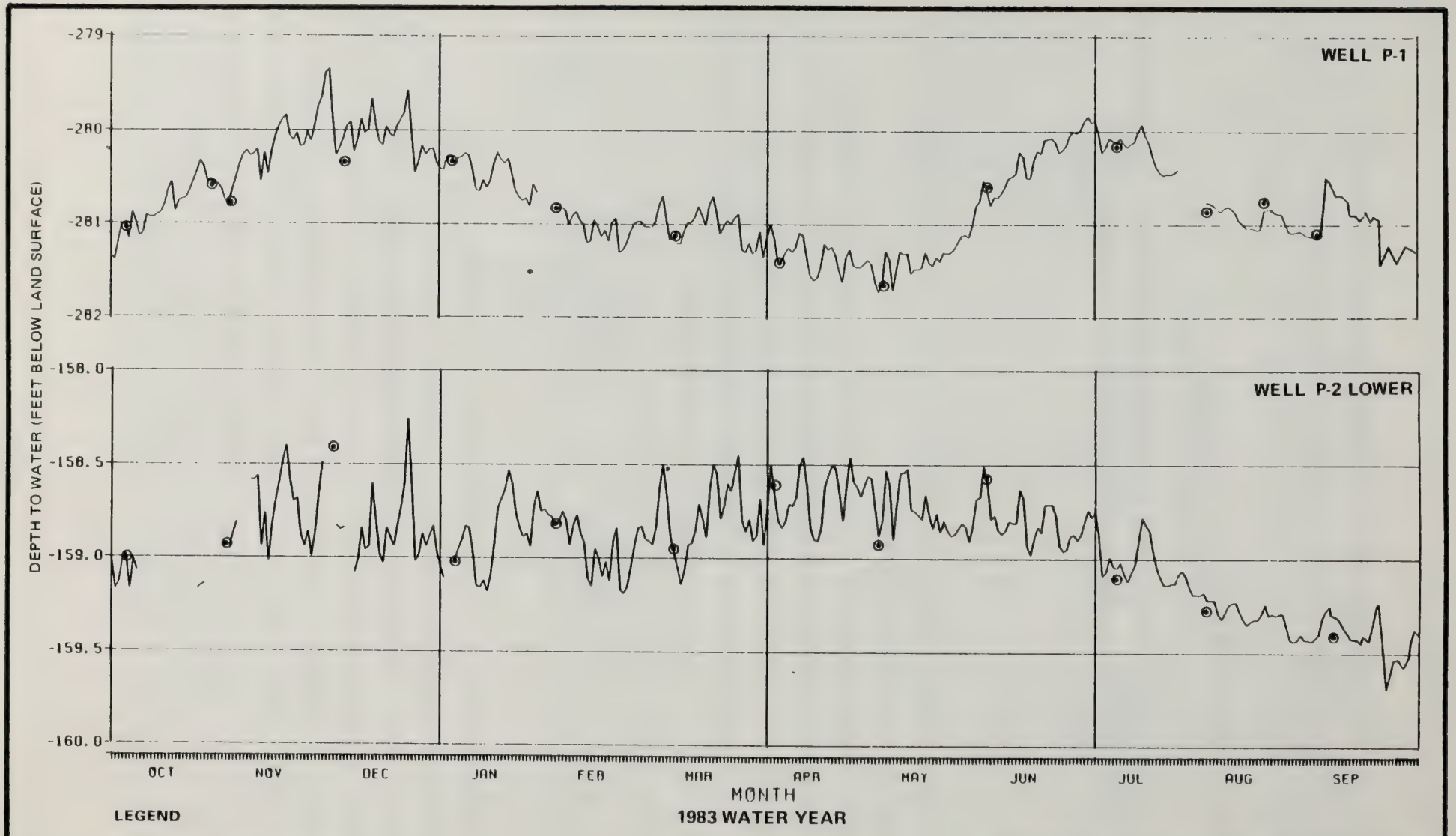
Annual extreme and mean water levels recorded at well P-1 during the 1983 water year are tabulated below.

Well P-1

Annual Extreme and Mean Daily Static Water Levels
(land surface elevation 5284.0 ft)

	Depth (ft.)	Elevation (ft.)	Date
Low	281.73	5202.3	5/3/83
High	279.35	5204.7	12/1/82
Mean	280.72	5203.3	

As shown on the P-1 hydrograph, Figure 6.4-14, water levels showed a rising trend from the beginning of the water year to December 1, 1982 when the high water level was reached. Water levels then declined slowly to the low water level on May 3, 1983. Water levels then recovered gradually to a second peak in early to mid July, followed by another declining trend through the end of the water year. This fluctuation is believed to represent a combination of normal seasonal variation and equilibration or rebounding of the piezometric



GROUND WATER LEVEL HYDROGRAPH
MEAN DAILY WATER LEVELS

NOTES: RECORD LOSS DUE TO EQUIPMENT MALFUNCTION
VERTICAL SCALES DIFFER ON HYDROGRAPHS

FIGURE 6.4-14

surface following rapid shifts in water level observed at P-1 beginning in early June, 1982. (The June, 1982 fluctuations were probably related to excavation blasting during road construction.) The 1983 mean annual water level at P-1 was 1 to 2 feet below the long-term average depth of 279 feet. The range in water levels at P-1 during the 1983 water year was about 2.4 feet.

Annual extreme and mean water levels recorded at well P-2 Lower during the 1983 water year are tabulated below.

Well P-2 Lower

Annual Extreme and Mean Daily Static Water Levels
(land surface elevation 4990.5 ft)

	Depth (ft.)	Elevation (ft.)	Date
Low	159.72	4830.8	9/20/83
High	158.26	4832.2	12/23/82
Mean	158.93	4831.6	

As shown on the P-2 Lower hydrograph, Figure 6.4-14, water levels were relatively stable at about 159 feet, but showed a very gradual declining trend during the last quarter. It appears that the steady trend toward declining water levels in this well (first observed in mid-1980) is continuing. Mean annual water level at P-2 Lower is about 5 to 6 feet below the long-term average depth of 153 to 154 feet. The range in water levels at P-2 Lower during the 1983 water year was about 1.5 feet.

Annual extreme and mean water levels recorded at well P-3 during the 1983 water year are tabulated below.

Well P-3

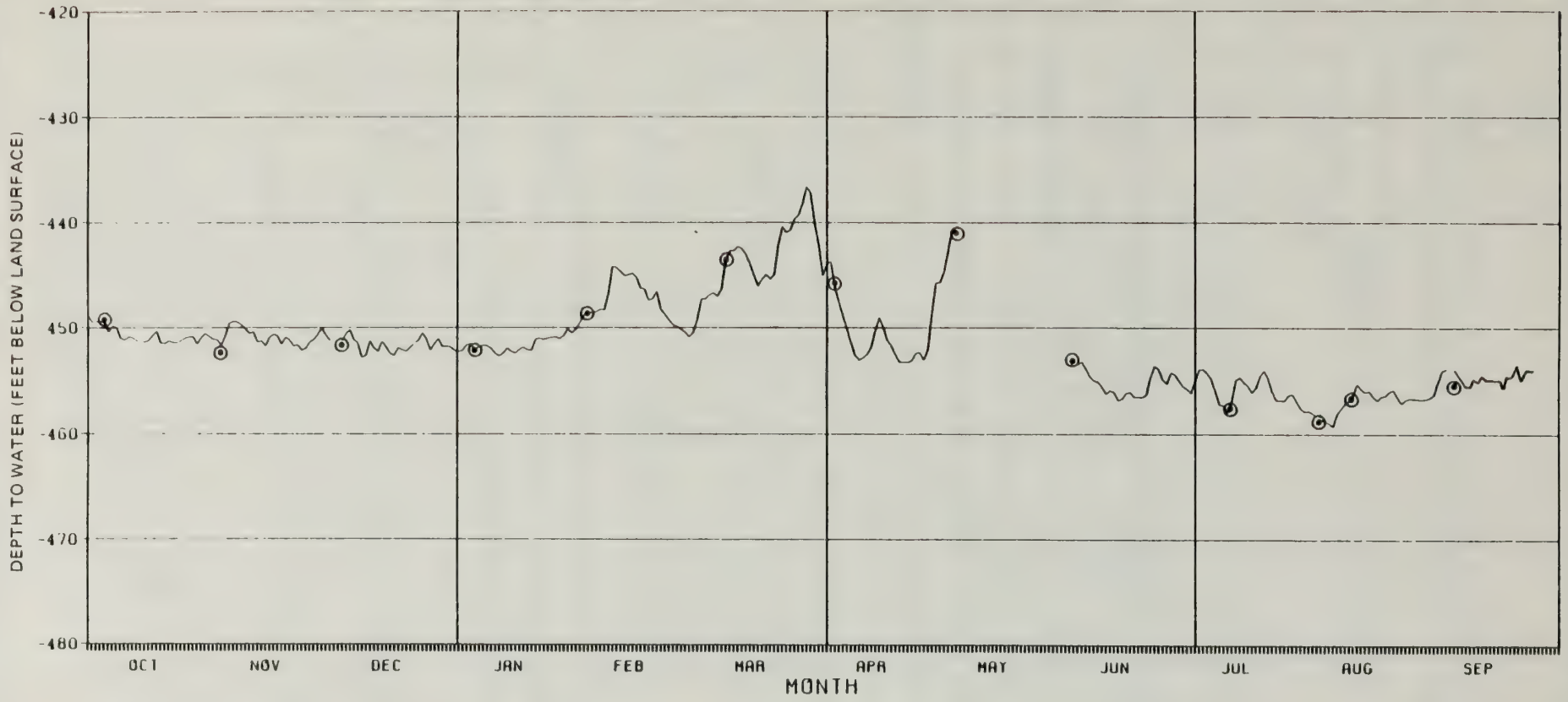
Annual Extreme and Mean Daily Static Water Levels

(land surface elevation 5486.0 ft)

	Depth (ft.)	Elevation (ft.)	Date
Low	459.28	5026.7	8/5/83
High	436.58	5049.4	3/28/83
Mean	451.51	5034.5	

As shown on the P-3 hydrograph, Figure 6.4-15, normal short-term water level fluctuations continued through January 1983. The mean water level up to that date had declined by one to two feet below the 1982 mean water level of 450 feet. Mean annual water levels have been relatively constant at about 450 feet since the 1979 water year. Beginning about the first week of February 1983, water levels began to rise rapidly through a series of three abnormally steep peaks punctuated by rapid intermediate declines. The water level reached its minimum depth of about 437 feet by the end of March. Following the three peaks, the water level dropped and has resumed a pattern of normal fluctuation at a depth of around 456 feet during the last quarter of the water year. This level is about 6 feet below the long-term average depth to water of about 450 feet. The extreme range in water levels at P-3 during the 1983 water year was about 22.7 feet.

Figure 6.4-16 shows mean monthly water level data for wells P-1, P-2 Lower, and P-3 for water years 1979-1983. Only the most recent five years of record are shown on this figure to represent long-term water level trends.



1983 WATER YEAR

WELL P-3

LEGEND

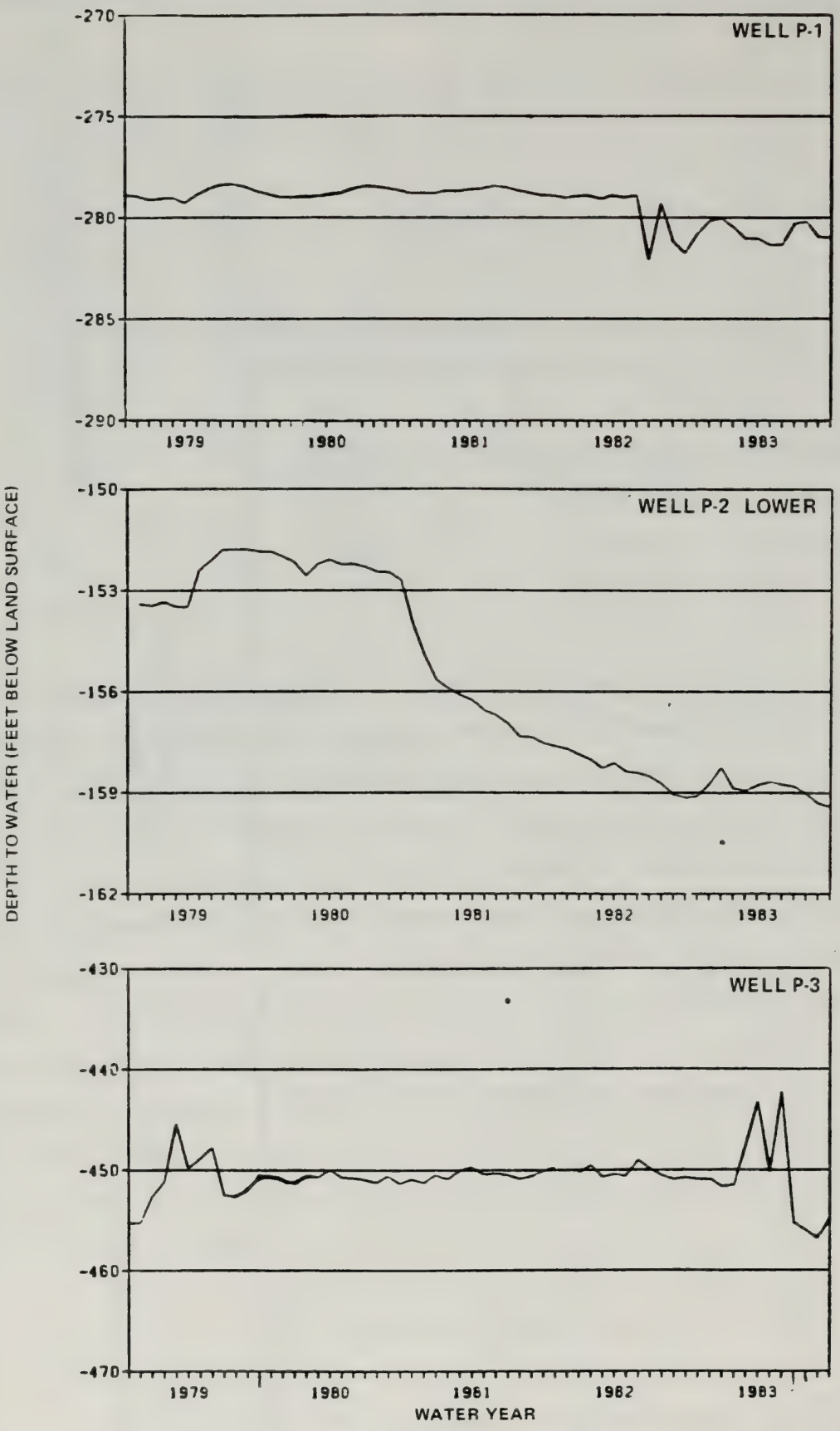
⊙ MANUAL MEASUREMENT

GROUND WATER LEVEL HYDROGRAPH

MEAN DAILY WATER LEVELS

NOTE RECORD LOSS DUE TO EQUIPMENT MALFUNCTION

FIGURE 6.4-15



GROUND WATER LEVEL HYDROGRAPH
MEAN MONTHLY WATER LEVELS

NOTE: VERTICAL SCALES DIFFER ON HYDROGRAPHS

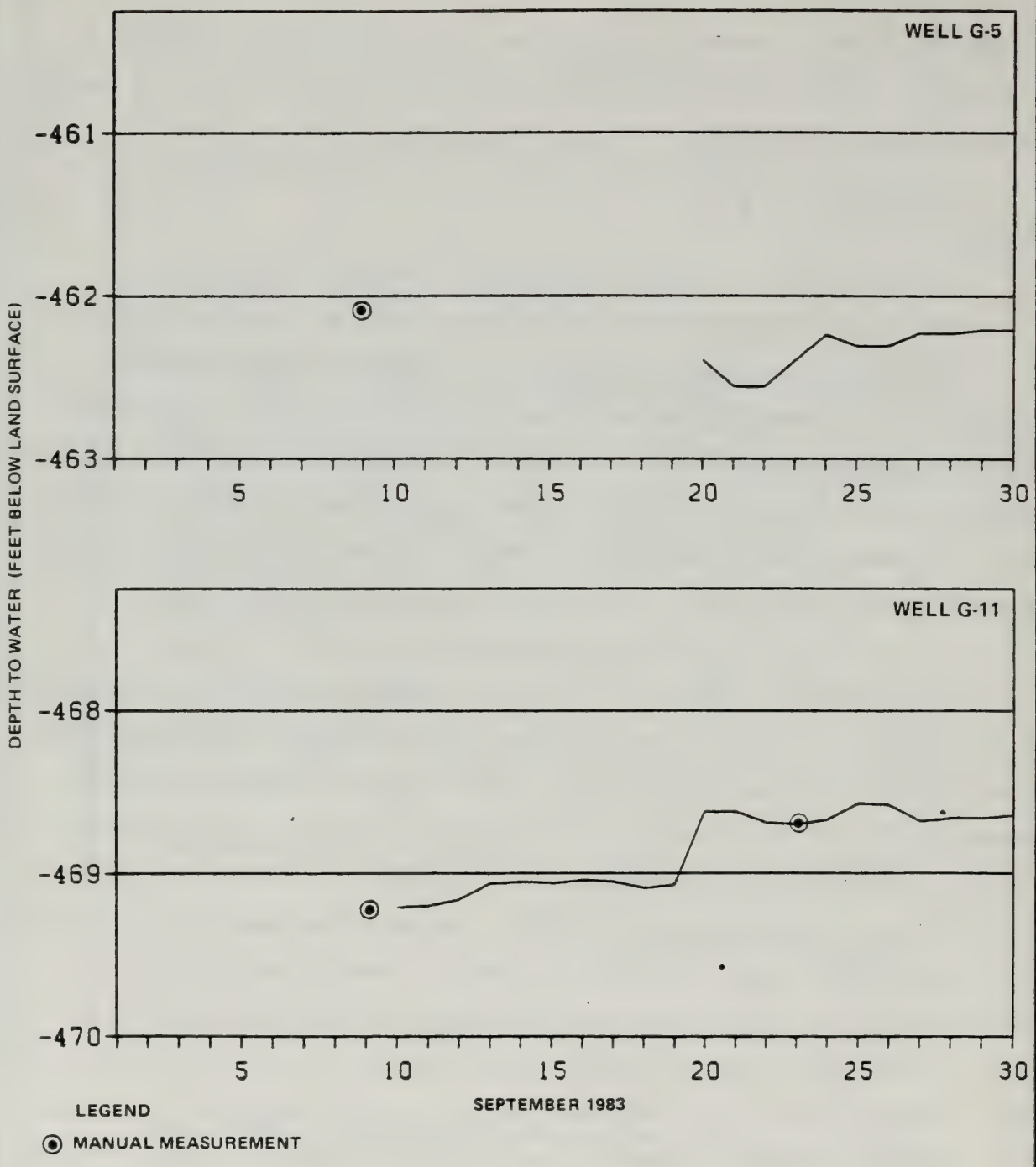
FIGURE 6.4-16

It was not deemed necessary to illustrate all of the period of record (1975-1983). The entire period of record has been considered in the analyses of static water level data.

G-Wells

Water level hydrographs for wells G-5 and G-11 are shown on Figure 6.4-17. Continuous water level recorders were operated at these wells only through the last month of the water year. Manual water level measurements for these wells and the five other G-wells for the entire water year are presented on Table 6.4-10. Long-term trends in water level at the G-wells for the 1979 through 1983 water years are shown on Figure 6.4-18. Again, only the most recent five years of record are illustrated in this figure.

As illustrated on Figure 6.4-18, water levels at most G-wells are about 5 to 10 feet below recent historic values. Water levels in these wells had risen about 2 to 4 feet above November 1978 values to a peak in April or November 1979 and have since declined to present levels. Minor exceptions to this general trend have occurred at G-8A, G-10 and G-11. Water levels at well G-8A have remained stable throughout the period of record, including the 1983 water year. Well G-11 had maintained high water levels beyond the period when other wells began to show declines, and has since exhibited a partial recovery of water levels during the last half of the 1983 water year. Well G-11 water levels have recovered to about 4 feet above mid 1983 levels. Water levels at G-10 are somewhat more difficult to assess, because the wide natural variations at this well have masked the slight rising and declining trends that are more clearly discernable at the other wells. However, a closer examination of the water levels of this well indicates a generally rising trend (comparable in magnitude to the same trend observed at the other G-wells) had occurred from the beginning of the 1979 water year. The first



GROUND WATER LEVEL HYDROGRAPH
MEAN DAILY WATER LEVELS
SEPTEMBER 1983

NOTE: RECORD LOSS DUE TO EQUIPMENT MALFUNCTION, CONTINUOUS RECORDERS INSTALLED 9/9/83.

FIGURE 6.4-17

TABLE 6.4-10

STATIC GROUND WATER LEVELS
FOR BIRD'S NEST ZONE WELLS

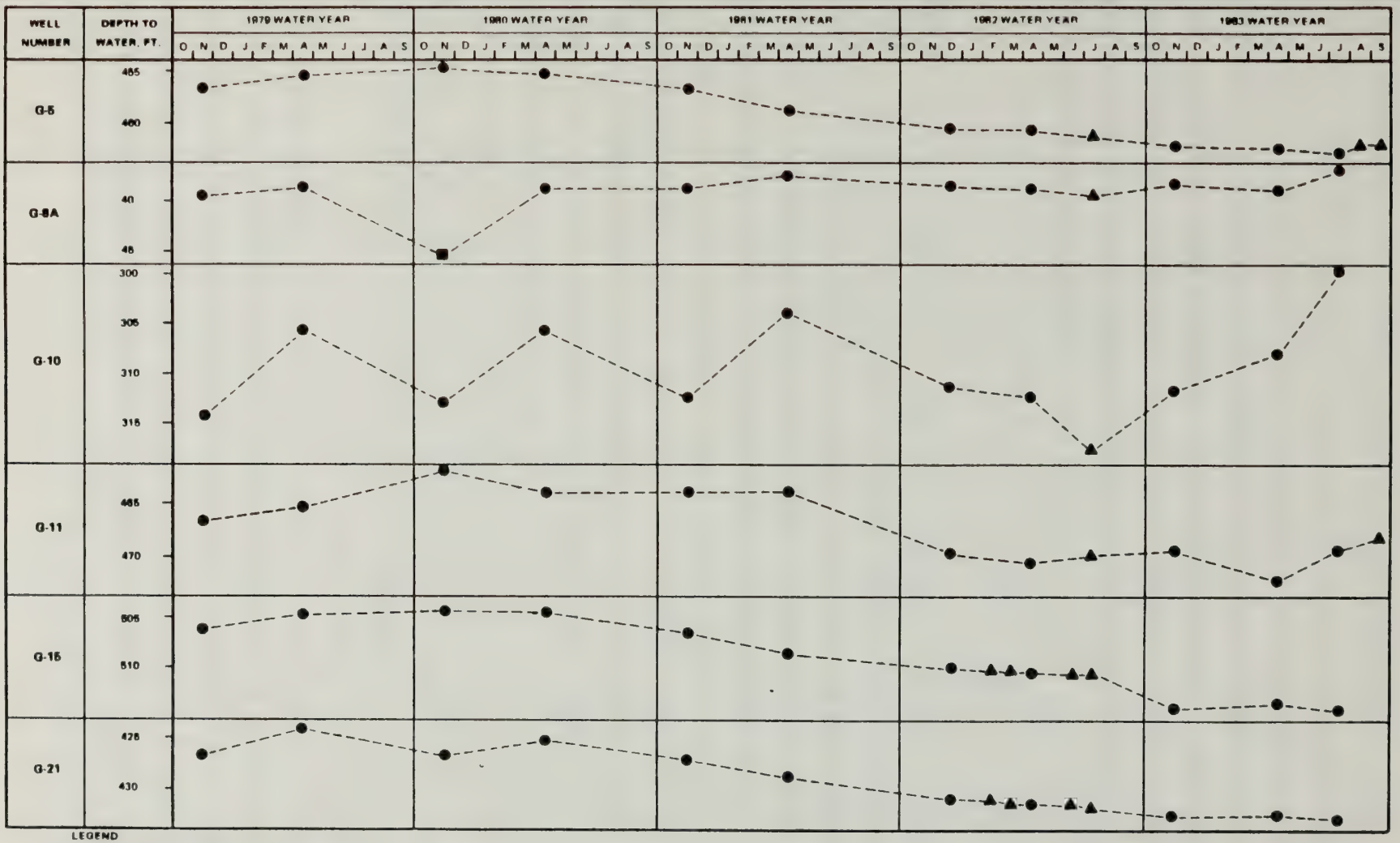
STATION NAME	DATE	TIME	DEPTH OF WELL (FEET)	ELEVATION OF LAND SURFACE DATUM (FEET)	WATER LEVEL (FEET BELOW LSD)	ELEVATION OF STATIC WATER LEVEL (FEET)
G-5	11/08/82	1210	600	5292.00	462.34	4829.66
	04/19/83	1150	600	5292.00	462.50	4829.50
	07/20/83	1445	600	5292.00	462.95	4829.05
	08/05/83	1030	600	5292.00	462.13	4829.87
	09/09/83	0948	600	5292.00	462.10	4829.90
G-8	11/08/82	1245	127	5095.50	50.20	5045.30
	04/19/83	1230	127	5095.50	50.02	5045.48
G-8A	11/08/82	1250	100	5095.00	38.00	5057.00
	04/19/83	1220	100	5095.00	38.57	5056.43
	07/27/83	1130	100	5095.00	36.70	5058.30
G-10	11/08/82	1230	400	5364.00	311.75	5052.25
	04/19/83	1215	400	5364.00	308.15	5055.85
	07/27/83	1115	400	5364.00	299.72	5064.28
G-11	11/08/82	1155	650	5375.00	469.90	4905.10
	04/19/83	1105	650	5375.00	472.90	4902.10
	07/27/83	1145	650	5375.00	470.00	4905.00
	09/09/83	1129	650	5375.00	469.21	4905.79
	09/23/83	1120	650	5375.00	468.70	4906.30
G-14	11/08/82	1330	90	5172.00	*	—
	04/19/83	1300	90	5172.00	*	—
	07/15/83	1300	90	5172.00	*	—
G-15	11/08/82	1045	627	5343.00	513.60	4829.40
	04/19/83	1015	627	5343.00	513.13	4829.87
	07/27/83	1015	627	5343.00	513.90	4829.10
G-21	11/08/82	0950	612	5262.00	432.32	4829.68
	04/19/83	0945	612	5262.00	432.40	4829.60
	07/27/83	0900	612	5262.00	432.95	4829.05

* NOTE: NO STATIC WATER LEVEL MEASUREMENTS WERE MADE IN 1983 AT WELL G-14 BECAUSE IT HAD BEEN OVERTOPPED BY EVACUATION CREEK FLOODS DURING THE SUMMER OF 1982 AND HAD FILLED WITH SILT.

TABLE 6.4-10 (continued...)

STATIC GROUND WATER LEVELS
FOR BIRD'S NEST ZONE WELLS

STATION NAME	DATE	TIME	DEPTH OF WELL (FEET)	ELEVATION OF LAND SURFACE DATUM (FEET)	WATER LEVEL (FEET BELOW LSD)	ELEVATION OF STATIC WATER LEVEL (FEET)
P-1	10/05/82	1400	480	5284.00	281.06	5002.94
	10/29/82	1400	480	5284.00	280.60	5003.40
	11/03/82	1300	480	5284.00	280.80	5003.20
	12/03/82	0900	480	5284.00	280.31	5003.69
	01/05/83	1200	480	5284.00	280.35	5003.65
	02/02/83	1100	480	5284.00	280.85	5003.15
	03/07/83	1300	480	5284.00	281.14	5002.86
	04/05/83	1300	480	5284.00	281.42	5002.58
	05/04/83	1000	480	5284.00	281.66	5002.34
	06/02/83	1000	480	5284.00	280.66	5003.34
	07/08/83	0900	480	5284.00	280.17	5003.83
	08/02/83	1200	480	5284.00	280.80	5003.20
	08/18/83	1100	480	5284.00	280.75	5003.25
	09/02/83	1100	480	5284.00	281.10	5002.90
P-2 LOWER	10/05/82	1100	580	4990.50	159.00	4831.50
	11/02/82	1100	580	4990.50	158.93	4831.57
	12/02/82	1000	580	4990.50	158.41	4832.09
	01/05/83	1100	580	4990.50	159.02	4831.48
	02/02/83	1000	580	4990.50	158.82	4831.68
	03/07/83	1300	580	4990.50	158.95	4831.55
	04/04/83	1130	580	4990.50	158.61	4831.89
	05/03/83	0900	580	4990.50	158.93	4831.57
	06/02/83	0900	580	4990.50	158.57	4831.93
	07/08/83	0800	580	4990.50	159.11	4831.39
	08/02/83	1000	580	4990.50	159.28	4831.22
	09/06/83	1400	580	4990.50	159.43	4831.07
P-3	10/05/82	1200	540	5486.00	449.20	5036.80
	11/03/82	1200	540	5486.00	452.32	5033.68
	12/03/82	0900	540	5486.00	451.60	5034.40
	01/05/83	1100	540	5486.00	452.13	5033.87
	02/02/83	1100	540	5486.00	448.55	5037.45
	03/08/83	0900	540	5486.00	443.50	5042.50
	04/04/83	1200	540	5486.00	445.70	5040.30
	05/04/83	0800	540	5486.00	440.85	5045.15
	06/02/83	1000	540	5486.00	452.97	5033.03
	07/11/83	0900	540	5486.00	457.50	5028.50
	08/02/83	1100	540	5486.00	458.73	5027.27
	08/10/83	1400	540	5486.00	456.75	5029.25
	09/06/83	1400	540	5486.00	454.46	5031.54



STATIC WATER LEVELS IN G-WELLS
WATER YEARS 1979 – 1983

FIGURE 6.4-18

notable decline in water levels for G-10 was observed in April 1982, at which time the water level was about 8 feet below the April 1981 value. The July 1981 value for G-10 was the lowest water level recorded at this well. By November 1982, water level at G-10 was normal in comparison to prior November measurements, indicating that water levels had begun to recover toward normal levels. The April 1983 value for G-10 was several feet below historical April values, indicating that complete recovery had not yet occurred. By July 1983, water level at G-10 was about 17 feet above the previous July water level, and had fully recovered and exceeded historic values.

Wells G-5 and G-11 have been monitored continuously for static water level beginning in September, 1983 to detect possible effects due to underground excavation through the Birds Nest Zone. Mine workings first penetrated the Birds Nest Zone in August, 1983. Water levels at well G-5 remained essentially stationary throughout the 1983 water year and are therefore believed not to have been effected. Water levels at G-11 rose notably beginning in April 1983 prior to penetration of the Birds Nest Zone. It is likely that the rise at G-11 is associated with the rise observed at well G-10 beginning about July, 1982. Well G-10 is located to the east and up gradient of well G-11. Thus, it is possible that a potentiometric wave or mound has migrated down gradient from G-10 to G-11 over the period July 1982 to April 1983. If so, and if the mound continues to propagate, then a similar rise may be observed at well G-5 (located to the southwest and down gradient of G-11) in early 1984.

In summary, the most notable water level observation in the Birds Nest Zone during the 1983 water year has been the unusual fluctuation at well P-3. While the water level fluctuation is within the historic extremes at this well, it occurred over an unusually short period compared to the relatively subdued fluctuations which are more typical of this well. The fluctuation is

in some respects similar to the abnormal fluctuations which occurred at well P-1 beginning in June 1982. Water levels at P-1 have since resumed a normal pattern of fluctuation during the 1983 water year, and observations at P-3 suggest water levels may be approaching a normal pattern at that location also. There is currently no explanation for the abnormal fluctuations at well P-3. However, a similar series of abrupt fluctuations occurred at this well during the 1979 water year and it is therefore probable the event is natural and not project-related.

Water level fluctuations at well G-10 were also notable. After following the general declining trend that had occurred at most Birds Nest Zone wells since the 1979 or 1980 water years, water levels at G-10 have recovered throughout the 1983 water year to the highest level recorded at this well. It is possible this rise in water level at G-10 is related to the abnormal peaks observed at well P-3 during the current water year.

The general trend of water levels for most of the Birds Nest Zone wells during the 1983 water year is toward gradually declining water levels. This trend has been occurring since about mid- to late 1979, following a slight overall increase in water levels prior to that time. It is probable that this gradual long-term trend has resulted from a combination of natural annual variations in recharge and discharge and possible ground water withdrawals in the area north and west of the tracts.

B. Water Quality Water quality samples were collected for laboratory analysis at each of two Bird's Nest Zone wells, G-5 and G-11. A comparison of the 1983 results to the baseline water quality data collected at these wells is shown in Table 6.4-11. All baseline data for the Birds Nest Zone wells were collected during the 1975 and 1976 water years.

TABLE 6.4-11

WATER QUALITY DATA SUMMARY
FOR WELLS G-5 AND G-11

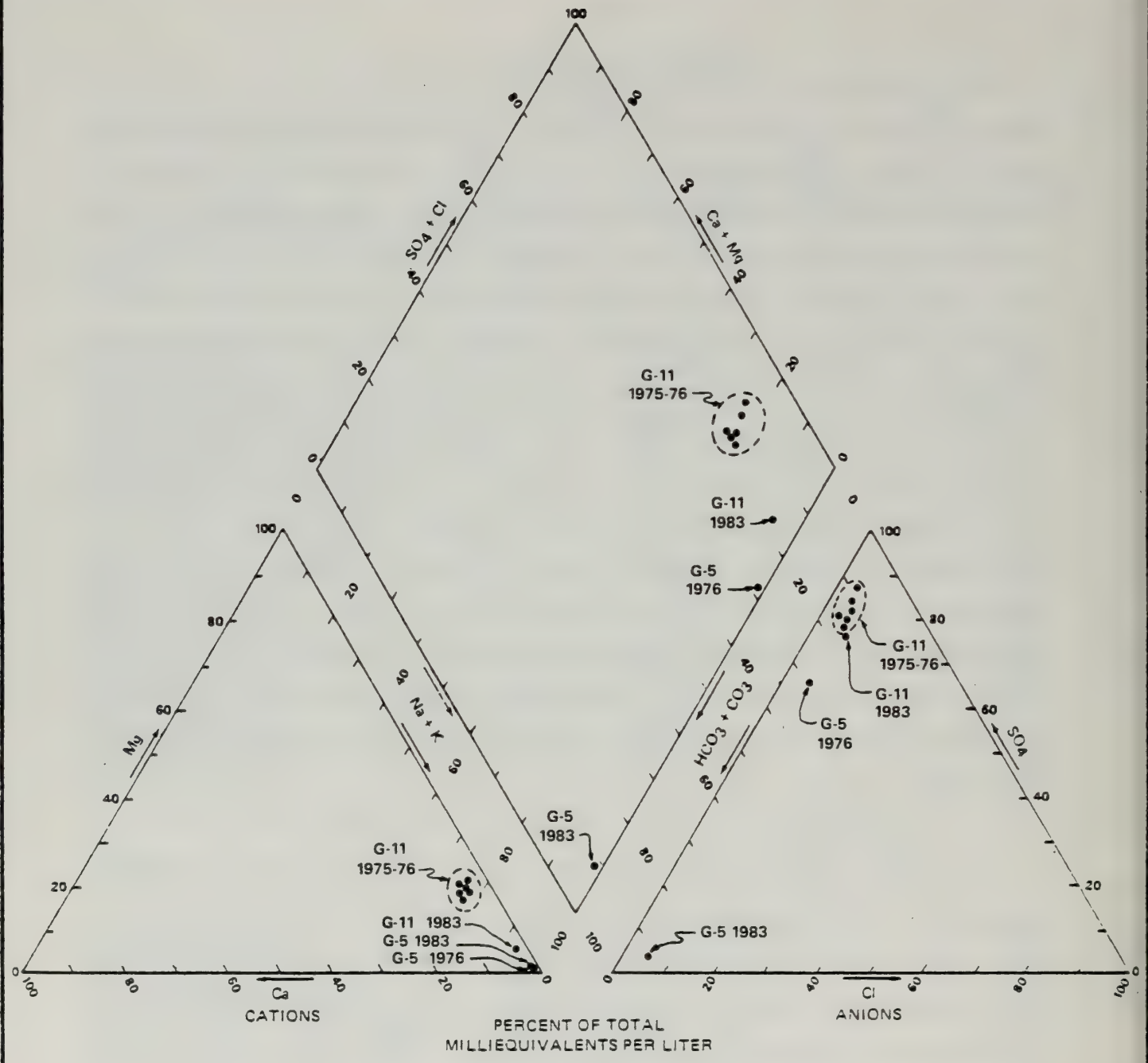
PARAMETER	1975 - 1976 NO. OF SMPLS	MIN.	MAX.	MEAN	STD. DEV.	1983 NO. OF SMPLS	MIN.	MAX.	MEAN	RMK.
WELL G-5										
WATER TEMPERATURE (DEG C)	1			17.50		1			17.50	
PH, FIELD (UNITS)	1			9.20		1			9.40	
SPECIFIC CONDUCTANCE FIELD (UMHOS)	1			2400.0		1			2325.0	
TOTAL DISS SOLIDS, RESIDUE @ 180c (MG/L)	1			1700.0		1			1490.0	
TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	1			1820.0		1			1452.8	
HARDNESS TOTAL (MG/L AS CACO3)	1			15.0		1			6.0	
NONCARB HARDNESS LAB (MG/L CACO3)	1			—		1			—	
ALKALINITY, LAB (MG/L AS CACO3)	1			400.0		1			1220.0	
SILICA, DISS (MG/L AS SIO2)	1			15.00		1			9.10	
CALCIUM, DISS (MG/L)	1			1.80		1			1.60	
MAGNESIUM, DISS (MG/L)	1			2.20		1			0.60	
POTASSIUM, DISS (MG/L)	1			1.80		1			1.70	
SODIUM, DISS (MG/L)	1			580.00		1			620.00	
SODIUM ADSORPTION RATIO	1			69.00		1			110.00	
PERCENT SODIUM	1			99.0		1			99.0	
SULFATE, DISS (MG/L)	1			740.00		1			17.00	
CHLORIDE, DISS (MG/L)	1			50.00		1			61.00	
FLUORIDE, DISS (MG/L)	1			1.30		1			9.70	
WELL G-11										
WATER TEMPERATURE (DEG C)	6	15.5	19.0	17.08	1.39	1			18.00	
PH, FIELD (UNITS)	6	7.5	8.4	7.92	0.39	1			9.60	*
SPECIFIC CONDUCTANCE FIELD (UMHOS)	6	5600	6100	5956.7	188.9	1			3800.0	**
TOTAL DISS SOLIDS, RESIDUE @ 180c (MG/L)	6	4310	4970	4735.0	226.0	1			3840.0	**
TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	6	4570	5090	4806.7	221.5	1			3814.2	**
HARDNESS TOTAL (MG/L AS CACO3)	6	750	920	836.7	61.2	1			150.0	**
NONCARB HARDNESS LAB (MG/L CACO3)	6	140	520	311.7	146.8	1			0.00	
ALKALINITY, LAB (MG/L AS CACO3)	6	365	610	526.5	97.0	1			548.0	
SILICA, DISS (MG/L AS SIO2)	6	24	27	25.17	1.17	1			<1.20	**
CALCIUM, DISS (MG/L)	6	48	69	63.00	7.59	1			6.00	**
MAGNESIUM, DISS (MG/L)	6	140	180	161.67	14.72	1			33.00	**
POTASSIUM, DISS (MG/L)	6	3.4	5.9	4.42	0.88	1			4.80	
SODIUM, DISS (MG/L)	6	1200	1300	1233.33	51.64	1			1200.00	
SODIUM ADSORPTION RATIO	6	18	19	18.67	0.52	1			43.00	*
PERCENT SODIUM	6	76	78	76.5	0.8	1			94.0	*
SULFATE, DISS (MG/L)	6	2600	3100	2800.00	200.00	1			2100.00	**
CHLORIDE, DISS (MG/L)	6	75	140	95.33	25.30	1			140.00	
FLUORIDE, DISS (MG/L)	6	0.90	1.2	1.05	0.12	1			0.60	**

NOTES: * = 1983 DATA EXCEEDED THE PREVIOUS MAXIMUM VALUE.
** = 1983 DATA EXCEEDED THE PREVIOUS MINIMUM VALUE
ONLY ONE SAMPLE DURING 1975-76 (09/17/76) IS PRESENTED FOR WELL G-5 BECAUSE OF UNSTABLE WATER QUALITY.

The baseline data presented for well G-5, includes only the last sample taken in 1976. The water quality at this well (as indicated by TDS) varied greatly during 1975, but stabilized in late 1976. Thus, the 1976 data are believed to be more representative of natural conditions at this well. The 1983 data collected at G-5 indicate a substantial change from the 1976 conditions. The specific conductance (2,325 umhos/cm) was only slightly lower than the 1976 value of 2,400 umhos/cm. However, the percentage contribution of the major anions and cations at G-5 showed a major shift, as shown in the trilinear diagram in Figure 6.4-19. This shift was evidenced as a change from a sodium-sulfate water type in September 1976 to a sodium-bicarbonate type in 1983. This was caused by greatly increased bicarbonate level (1,220 mg/l) and a low level of sulfate (17 mg/l) in the 1983 sample. A similar decrease in the concentration of sulfate occurred at well G-11 in 1983. For this reason, the 1983 sample plots slightly below the baseline cluster of samples shown in Figure 6.4-19. The specific conductance at G-11 decreased to 3,800 umhos/cm in 1983, compared to the 5,600 - 6,100 umhos/cm range in 1975-1976.

The water quality samples taken at G-5 and G-11 during 1983, were collected with a thief sampler <u>without</u> pumping out the stagnant water in the well casing. Thus, the 1983 data <u>may not</u> be representative of actual ground water conditions. This is further evidenced by a recent sample that was pumped from G-11 in December 1983. The specific conductance of this sample was 5,900 umhos/cm, which would indicate little change in this parameter from baseline conditions.

In summary, the water quality data for August 31, 1983 samples collected at G-5 and G-11 are considerably different from baseline water quality data for these wells. However, the data are considered to be questionable because of the method of sample collection. No conclusions can be reached at this



TRILINEAR DIAGRAM SHOWING WATER QUALITY TRENDS AT WELLS G-5 AND G-11

FIGURE 6.4-19

time concerning water quality conditions for the Birds Nest Zone. (It is planned that water quality samples will be collected at all Birds Nest Zone wells during the 1984 water year using appropriate methodology.)

6.4.3.2 Uinta Formation Unlike the Birds Nest Zone, the portions of the Uinta Formation monitored on the tracts do not appear to constitute a pervasive water-bearing zone. Rather, ground water appears to occur in localized areas where adequate recharge and rock porosity is available. Wells P-2 Upper and UF-1 were completed in water bearing zones at the base of the Uinta Formation.

A. Water Levels Water level data are presented below separately for wells P-2 Upper and UF-1, followed by a brief summary of findings.

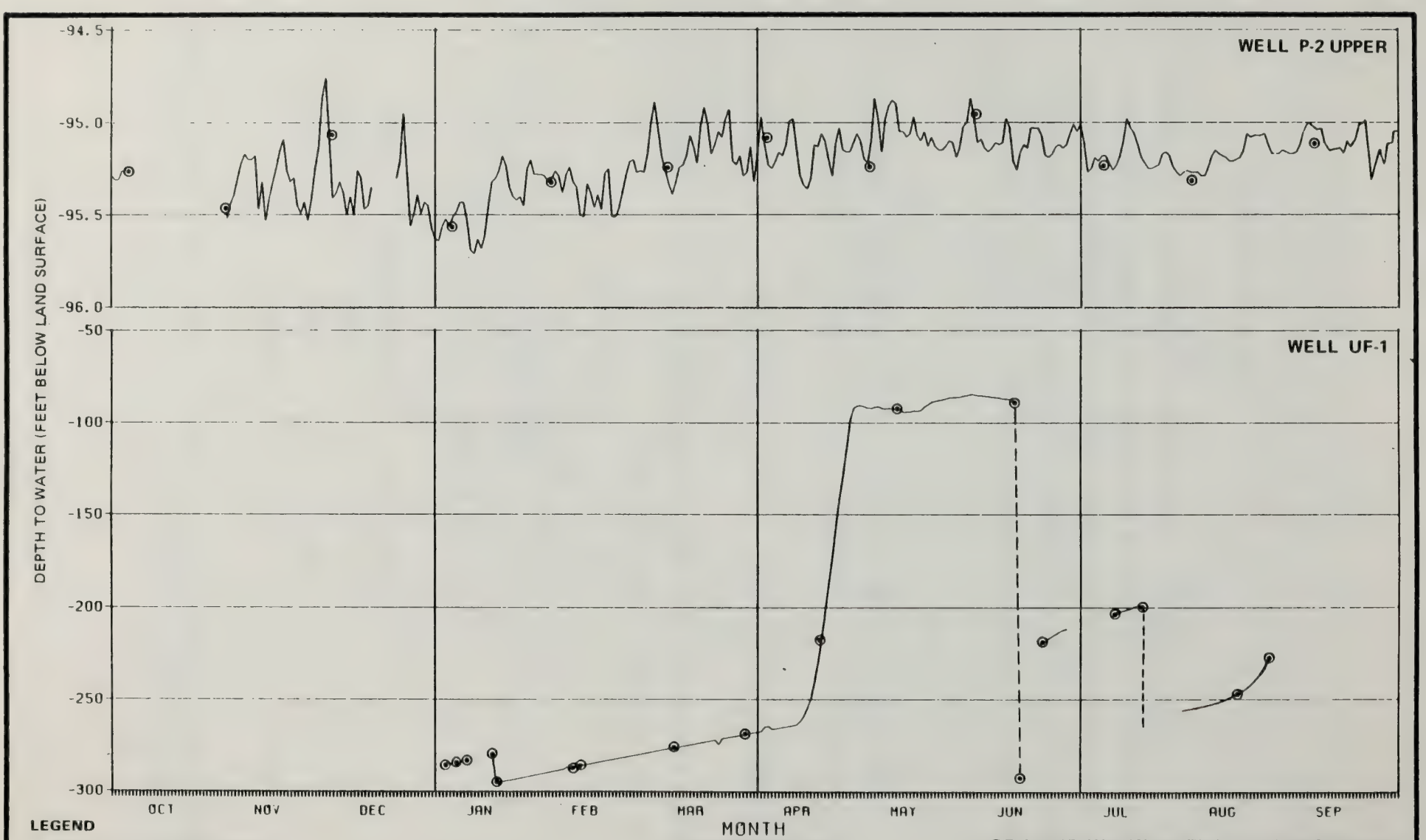
Well P-2 Upper

Annual extreme and mean water levels recorded at well P-2 Upper during the 1983 water year are tabulated below.

Well P-2 Upper
Annual Extreme and Mean Daily Static Water Levels
(land surface elevation 4991.0 ft.)

	Depth (ft.)	Elevation (ft.)	Date
High	94.76	4896.2	12/1/82
Low	95.71	4895.3	1/12/83
Mean	95.21	4895.8	

As shown on the P-2 Upper hydrograph, Figure 6.4-20, water levels were nearly stationary at about 95 feet below land surface throughout the 1983 water



GROUND WATER LEVEL HYDROGRAPH
MEAN DAILY WATER LEVELS

FIGURE 6.4-20

year. The range in water levels at P-2 Upper during the 1983 water year was 0.95 feet. Static water levels at P-2 Upper from the 1977 through 1983 water years were relatively stable; pumping of the well (for water quality sampling and aquifer tests) during the 1975 and 1976 water years caused some minor instability in water levels.

Well UF-1

A continuous water level hydrograph for well UF-1 is shown on Figure 6.4-20. A continuous water level recorder was operated at this well only during the last three quarters of the water year. A dramatic rise in water level began in mid-April at the same time that water from the cut-off trench for the retention dam was initially pumped to an unlined pit near this well. The water level rose rapidly from 263.4 feet on April 13 to 90.7 feet on May 1, and then stabilized between 85 and 95 feet through June 13. It is believed that the sudden rise in water level was due to water that had percolated out of the pit into the alluvium and underlying bedrock and subsequently entered the well borehole below its surface casing. The well was pumped on June 15 and July 20, 1983 to remove this water. On August 25, 1983, well UF-1 was recompleted as a multiple-tube well containing four separate tubes to measure water levels at various depths in the Uinta Formation. The new well is one of seven wells now monitoring for potential leakage from the Plant Site Wash retention dam.

In summary, analysis of water levels at P-2 Upper and UF-1 indicate relatively stable long-term conditions at P-2 Upper, and initially very limited natural ground water at UF-1 followed by increased water levels resulting from dam construction activities.

B. Water Quality No samples were collected in 1983 from well P-2 Upper. Water quality samples were collected at two occasions (January 7 and May 12, 1983) from well UF-1. Table 6.4-12 presents laboratory analyses for the January 7 sample. The January sample is believed to represent natural ground water quality prior to percolation of water into the well. The water present in the well on May 12 is believed to have been affected by construction materials (e.g., Portland cement) and by leached minerals from the dam construction area, thus it is not representative of natural conditions. The water that entered the UF-1 borehole in April and May 1983 probably caused temporary and localized degradation of natural water quality conditions in the water bearing zone. As indicated in Section 6.4.3.2A, efforts have been undertaken by WRSOC to remove this water and prevent any extensive water quality degradation.

6.4.3.3 Southam Canyon Alluvium Ground water conditions in the Southam Canyon alluvium are monitored at four wells. However, only well AG-6-1, has contained water during the entire period of record. Therefore, the water level and water quality discussion is limited to conditions at AG-6-1.

A. Water Levels Water level data for the 1983 water year at well AG-6-1 are presented in Table 6.4-13. Long-term trends in water level at well AG-6-1 for the 1979 through 1983 water years are shown on Figure 6.4-21. As for the previous ground water discussions, only the most recent five years of record are shown on this figure to represent long-term trends. High water levels coincided with high stage values for the nearby White River, indicating that the stage of the river has affected water levels in alluvial sediments adjacent to the river.

B. Water Quality Water quality data for the 1983 water year at well AG-6-1 are presented in Table 6.4-13. Long-term trends in specific conduct-

TABLE 6.4-12

WATER QUALITY DATA
FOR WELL UF-1

DATE	TIME	DEPTH OF SAMPLE (FT FM SUR-FACE)	WATER TEMPER-ATURE (DEG C)	PH, FIELD (UNITS)	PH, LAB (UNITS)	SPECI-FIC CONDUC-TANCE FIELD (UMHOS)	TOTAL DISS SOLIDS, RESIDUE @ 180c (MG/L)	TOTAL DISS. SOLIDS, CALC. SUM (MG/L)	HARD-NESS TOTAL (MG/L AS CACO3)
01/07/83	1020	287	12.0	9.7	9.7	1850	1430	1381	17

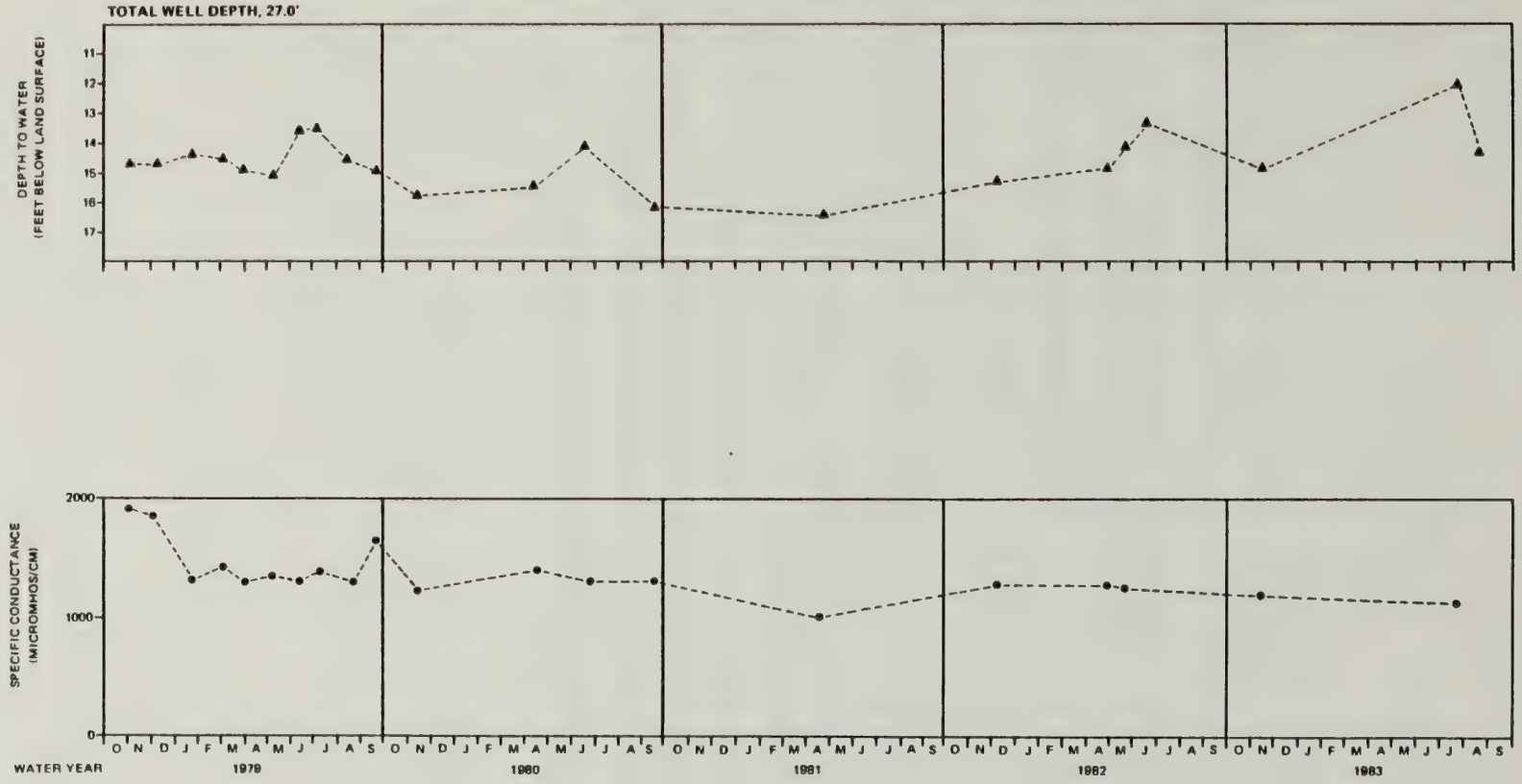
DATE	TIME	HARD-NESS, NONCAR. (MG/L AS CACO3)	ALKALI-NITY, LAB (MG/L AS CACO3)	SILICA, DISS (MG/L AS SIO2)	CAL-CIUM, DISS (MG/L)	MAGNE-SIUM, DISS (MG/L)	POTAS-SIUM, DISS MG/L)	SODIUM, DISS (MG/L)	SODIUM ADSORP-TION RATIO
01/07/83	1020	0	811	8.2	3.0	2.3	2.9	530	57

DATE	TIME	PERCENT SODIUM	SUL-FATE, DISS (MG/L)	CHLOR-IDE, DISS (MG/L)	FLUOR IDE, DISS (MG/L)	BORON, DISS (UG/L)
01/07/83	1020	98	270	73	3.1	960

TABLE 6.4-13

STATIC GROUND WATER LEVELS AND WATER QUALITY FOR ALLUVIAL WELLS

STATION NAME	DATE	TIME	DEPTH OF WELL (FEET)	ELEVATION OF LAND SURFACE DATUM (FEET)	WATER LEVEL (FEET BELOW LSD)	ELEVATION OF STATIC WATER LEVEL (FEET)	SAMPLING CONDITION CODE	WATER TEMPERATURE (DEG C)	SPECIFIC CONDUCTANCE FIELD (UMHOS)	PH, FIELD (UNITS)
AG-6-1 LOWER	11/12/82	1025	27	4920.00	14.90	4905.10	—	13.0	1200	8.0
	07/27/83	0900	27	4920.00	12.05	4907.95	—	13.5	1150	7.8
	08/18/83	1245	27	4920.00	14.40	4905.60	—	—	—	—
AG-7	11/08/82	1120	39	5505.00	—	—	DRY	—	—	—
	04/19/83	1040	39	5505.00	—	—	DRY	—	—	—
	07/27/83	1030	39	5505.00	—	—	DRY	—	—	—
G-2A	11/08/82	1015	40	5056.00	—	—	DRY	—	—	—
	04/19/83	0955	40	5056.00	—	—	DRY	—	—	—
	07/27/83	0915	40	5056.00	—	—	DRY	—	—	—
G-4A	11/08/82	1055	20	5345.50	—	—	DRY	—	—	—
	04/19/83	1025	20	5345.50	—	—	DRY	—	—	—
	07/27/83	1020	20	5345.50	—	—	DRY	—	—	—



LEGEND

▲ WATER LEVEL FIELD MEASUREMENT

● SPECIFIC CONDUCTANCE FIELD MEASUREMENT

----- INTERPOLATED VALUES, MAY NOT REPRESENT ACTUAL CONDITIONS BETWEEN MEASUREMENTS

STATIC WATER LEVELS AND SPECIFIC CONDUCTANCE IN WELL AG-6-1
WATER YEARS 1979 – 1983

FIGURE 6.4-21

ance at well AG-6-1 for the 1979 through 1983 water years are shown on Figure 6.4-21. The specific conductance values at this well have been relatively stable since the middle of the 1979 water year.

6.4.3.4 Retention Dam Wells The retention dam monitoring well network consists of seven wells which were installed in the Uinta Formation and alluvium below the Plant Site Wash retention dam in August and September, 1983. The drilling and completion of these wells is described in another WRSP report (VTN 1984c). Initial water levels were recorded at several of the wells immediately following installation. No water quality data were collected at these wells during the 1983 water year.

Water level measurements were made primarily for the purpose of testing the wells for proper construction and are not adequate in number to delineate water level conditions for environmental monitoring purposes. While no free ground water was observed in the boreholes during drilling, these subsequent measurements indicate that water had entered several of the wells after they were completed. The initial tests also indicated that this water occurred in discrete vertical intervals suggestive of perched zones.

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SPECIAL STUDIES

7.0 SPECIAL STUDIES

The White River Shale Oil Corporation has identified several areas of study important to our evaluation of the environmental impacts of development on Tracts Ua and Ub. During 1983, the major areas of study consisted of the following: reclamation research (Section 7.1), spacial and temporal dynamics of selected heavy metals in the White River (Section 7.2) and vegetal and soil characteristics influencing rodent populations (Section 7.3).

7.1 RECLAMATION RESEARCH

7.1.1 Introduction

Reclamation research during 1983 was a combination of several ongoing studies and studies initiated either in late 1981 or 1982. Each study is directed to one or several of the "questions to be answered" itemized in the 1982 White River Shale Oil Corporation Environmental Monitoring Manual (EMM Sec. 7.2.3). Recently initiated research includes the establishment of a topsoil storage pile near the mine services building to identify any changes in soil microbiology that may occur with long term storage and to evaluate methods of stabilizing soil storage piles while maximizing the soil microflora. In the fall of 1981, a study was begun to assess various methods for enhancing wildlife habitat on areas adjacent to the plant site and processed shale disposal areas. This study was repeated with some modifications in 1983. Other evaluations conducted during 1983 were ongoing studies. These include the processed shale plant succession study started in 1981; evaluation of root growth in processed shale, an ongoing project since 1979; soil analysis indicating plant tolerance levels and salt buildup now in its fourth year; and plant establishment plots both on disturbed areas and processed shale, also started in 1979.

The reclamation research completed to date has provided information pertinent to the revegetation of disturbed areas and of processed shale (Van Epps and McKell, 1976, 1978, 1980; McKell, 1978, 1980). Numerous plant species have been identified and methodologies tested that will provide valuable direction in meeting the criteria for successful revegetation for oil

shale tracts Ua and Ub (McKell, 1978, 1980; Richardson and McKell, 1979, 1980, 1982; Van Epps and McKell, 1978, 1980; Institute for Land Rehabilitation, 1979; Barker and McKell, 1979; Richardson, et al., 1981; Call and McKell, 1982; Wagenet et al., 1982). Reclamation research for the WRSP continues under the direction of Dr. Cyrus M. McKell of NPI (Native Plants, Inc.).

7.1.2 Program Summary

7.1.2.1 Annual Plant Succession on Processed Shale Natural plant succession onto processed shale disposal piles at Anvil Points was not evaluated in 1983 because the site was destroyed by construction activities at Anvil Points. This will no longer be a part of the reclamation program until processed shale is available on the tracts.

7.1.2.2 Root Growth in Shale A detailed analysis of root growth into processed shale was made in 1983. Soil samples were taken from several depths under each of five species and root material was extracted. Root biomass averaged .23 g/1000g of soil. Root biomass was significantly less in the surface (0-2 cm) samples (shale and topsoil), but there were no significant differences between root volume of the topsoil samples and processed shale samples at lower depths. Roots were most abundant at the 15 cm depth for both soil and shale and at the bottom of the topsoil trench directly above the compacted layer of processed shale.

7.1.2.3 Migration of Salts in Soil Trenches Analysis of the soil filled trench at Anvil Points followed the format used in 1981-82. Differences in pH, EC and elemental content were apparent between soil and shale at various levels as determined by ANOVA and LSD mean separation tests. The surface

shale sample had significantly higher pH and EC values. Other shale samples also tended to have significantly higher pH and EC values than the soil samples. After three years since its establishment, changes in the pH are becoming evident. Overall pH raised 1.61 from 7.92 in June of 1981 to 8.53 in June 1983. The values for EC exhibit no such increase, indeed the values for 1981 and 1983 were identical (5.8).

7.1.2.4 Plant Establishment Studies From October 1982 to October 1983, five plants were lost at the Anvil Points study site and two others which were recorded as dead in 1982 resprouted from the living tissues in the roots. Four individuals of the genus Atriplex died: 1 cuneate saltbush (A. cuneata), two mat saltbushes (A. corrugata) and, one shadscale (A. confertifolia), all from the soil-shale microenvironment study area, and one prostrate kochia (Kochia prostrata) from the flat plantings. The two root sprouted plants included one greasewood (Sarcobatus vermiculatus) from the basin plantings and one seepweed (Sueda fruticosa) from the north soil trench. Percentage survival of the species used in the trench plantings, basin plantings and flats plantings as of June 1983 are as follows: fourwing saltbush (Atriplex canescens) 95%; shadscale 63%; cuneate saltbush 83%; western wheatgrass (Agropyron smithii) 95%; greasewood 100%; prostrate kochia 40%; and seepweed from trench plantings only 50%. Both plant heights and cover values were higher in 1983 indicating that growth continued in the fifth year of the experiment.

7.1.2.5 Topsoil Stockpile Study A second phase of the topsoil storage pile study was initiated in 1983. This study was designed and installed at

the actual topsoil storage pile near the mine services building. The previous pile was at section 6 and was very limited in size. Treatments at the new site consisted of two different seed mixes, two fertilizer regimes, three replications of each treatment combination, plus controls. The treatments will be sampled for total organic carbon, total bacteria, total fungal hyphae length, respiratory activity, dehydrogenase activity, pH, EC and percent moisture during 1984. Populations of vesicular arbuscular mycorrhizal (VAM) fungi will also be determined.

7.1.2.6 Interseedings and Interplanting for Wildlife Habitat Enhancement Two areas, one with substantial annual plant cover and one with less than 5% annual plant cover, were seeded with a standard shrub/grass mix in October of 1981. Seed application was drill and broadcast. A few seedlings were observed in the drill seeded area in June 1982. By fall, 1982 none were observed in the entire seeded area and none were found in June or October of 1983.

Transplants of big sagebrush (Artemisia tridentata), fourwing saltbush, gardner saltbush (A. gardneri), and rubber rabbitbrush (Chrysothamnus nauseosus) were also planted in both areas (high and low annual plant cover). In June of 1982 plants of all four species were found although survival percentages varied; however, only sagebrush survived until October of 1983. The greatest cause of mortality during this period was primarily due to rodents and rabbits. The results of heavy grazing was evident on the majority of the non-living species as well as those still showing signs of growth. Thus, in October of 1983 this study was reinitiated utilizing techniques to

protect both seedling and transplants from animal damage until they become established. Eighty plants of four species (sagebrush, fourwing saltbush, shadscale, and rabbitbrush) were planted. One half of all the plants were protected with Vexar™ tubing while the other half had no protection. By November of 1983 only sagebrush survived of the unprotected plants, while survival was over 99% for all of the protected plants.

7.1.3 Program Description

7.1.3.1 Objectives The objective of the reclamation research conducted by NPI is for the ultimate development of a successful revegetation plan for the oil tracts Ua and Ub. Several secondary objectives have directed the efforts in reclamation research. These include the:

- characterization of processed shale relative to its reclamation potential;
- determination of the tolerance and response of various plant species to disturbed areas and processed shale for reclamation and enhancement of wildlife habitat;
- development of plant establishment methods for processed shale disposal areas and disturbed sites; and
- measurement of the response of microbial activity in topsoil storage piles to long term storage.

7.1.3.2 Study Site Locations Reclamation research has been conducted at several sites on or adjacent to oil shale tracts Ua and Ub since the acquisition of baseline data in 1975. Since that time, two areas have been designated for ongoing research studies. One is at Anvil Points, Colorado, and the other at

Section 6 near Bonanza, Utah. The layout of both study sites has been presented in previous reports (see the 1980 final report (Native Plants, Inc., 1981) for the field plot designed and layout at Anvil Points and the 1982 report (WRSOC, 1983) for studies at Section 6).

7.1.3.3 Quality Assurance/Quality Control Precautions were taken to assure that the quality of the research conducted would meet those guidelines outlined in the EMM (Section 3.3.1 and 3.3.2). In some cases, the scope of the project was simplified to allow adequate sampling and greater confidence of the results. All reclamation research studies were set up and conducted to test one of several hypotheses detailed in the EMM (Section 7.2.3).

Soils analysis was the area for most concern in the QA/QC program. To assure quality, duplicate samples were analyzed on selected soils. Also, soils were analyzed by only certified labs. Sample handling is important in the topsoil microbiology samples, since heat and time will create an incubation of the organism (bacteria and fungi) and artificially increase their numbers. This is what occurred with the 1981 samples. The samples will be cooled within a few minutes of being taken and kept in cold storage (walk in refrigerator) until analysis. Analysis begins as soon as the soils are received in the lab to also reduce any incubation time.

Soil analysis methods are standardized, yet, there is often considerable variation when analyzing for particular elements. This suggests that the variability is in the soil matrix and care must be taken in deriving conclusions about differences in elements with high variability.

7.1.4 Program Results And Analysis

7.1.4.1 Annual Plant Invasion of Shale Disposal Piles In 1981, permanent plots were established on a shale disposal pile at Anvil Points to monitor and document the natural succession of weedy annual species onto the pile. Photographs, density and cover data were taken in 1981 and 1982 and was to be taken again in 1983. Upon visiting the Anvil Points site in June of 1983, it was learned that the shale disposal area had been leveled and was being used as an equipment and vehicle storage area. This promising area of research was thus discontinued as of 1983.

7.1.4.2 Root Growth in Processed Shale During excavations for soil analysis in processed shale, rhizomes and smaller roots of Western wheatgrass were noted growing in shale material adjacent to the soil filled trench. Also, shrub roots were observed growing throughout the soil trench profile and in the underlying processed shale material. Thus, in 1983 a more detailed sampling and analysis was conducted.

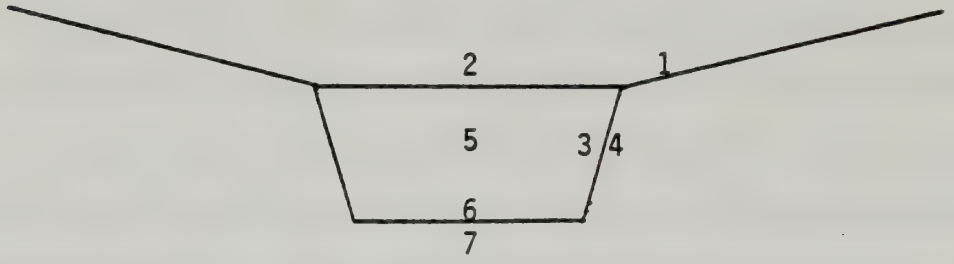
Sampling occurred in June 1983 at the north and south trenches at Anvil Points. Samples were taken from transects at the ends of both trenches and bisecting the five species planted in the end replications of each trench and perpendicular to the axis of the trench. Every species was sampled four times. Due to the destructive nature of the sampling the ends of each trench were selected as the area to sample. Thus, replications 1 and 10 for both the north and south trench were utilized (these will be excluded from further analyses on the plant establishment studies). This enabled the bulk of the trenches to remain intact and avoided any interactions that could influence the validity of

the other studies occurring at the site.

Soil samples were taken at seven depths under each species (Figure 7.1-1a, b). Approximately 800 grams of soil were taken at each depth, placed in ziplock bags and returned to NPI for analysis. In the laboratory the soils were weighed and the roots extracted manually. The root material was weighed and a root weight to soil weight was calculated. These ratios were tested by analysis of variance (ANOVA). The ANOVA results are shown in Table 7.1-1. Western wheatgrass had the highest average root biomass with .3982 g/1000g of soil while greasewood had the lowest at .1950 g/1000g of soil, however, none of the five species were significantly different. ANOVA results comparing root biomass at the various depths did snow significant differences. The surface samples (shale and soil) had the lowest root weights (Table 7.1-1). The 15 cm samples (shale and soil) and the 60 cm shale samples had the highest root weights (.4077, .3807, and .5521 g/1000g soil, respectively).

The high root biomass in the 60 cm shale sample occurred just above or right at the compacted shale layer and biomass would decrease rapidly at lower depths. This suggests that a compacted shale zone could be used to restrict water movement into a shale disposal pile. Water accumulating at that interface could be utilized by deep rooted shrubs and may actually function as a perched water table. Researchers have been concerned that roots would stay within the soil trench and not penetrate the shale, however, this data supplies sufficient evidence that roots will venture into the shale particularly if the shale is not compacted. The root biomass at the 15 cm depth was not different between the soil and shale samples.

Figure 7.1-1(a) Position in the topsoil at Anvil Points where samples were taken for root and chemical analysis.



1. 0-2 cm shale
2. 0-2 cm topsoil
3. 15 cm topsoil
4. 15 cm shale
5. 30 cm topsoil
6. 45 cm topsoil
7. 60 cm shale

Figure 7.1-1(b) Photo showing actual sampling for roots at Anvil Points.

Table 7.1-1. Root weights (g) per 1000 g of soil taken from Anvil Points on June 6, 1983. Values followed by common letters are not significantly different as tested by ANOVA and LSD ($F \leq .01$ and $P \leq .05$).

Depth	AGSM*	ATCA	ATCO	ATCU	SAVE	$\bar{X}$
0-2 cm shale	.0206	.0084	.0214	.0160	.0712	.0275[a]
0-2 cm soil	.1183	.0758	.0290	.1051	.0212	.0699[a]
15 cm shale	.5520	.5489	.3413	.3020	.2941	.4077[bc]
15 cm soil	.4715	.6450	.3350	.1506	.3015	.3807[bc]
30 cm soil	.2760	.1893	.1003	.1763	.1386	.1760[ab]
45 cm soil	.1656	.1138	.2146	.1794	.3153	.1977[ab]
60 cm shale	1.1836	.3960	.4632	.4940	.2236	.5521[c]
$\bar{X}$	.3982[a]	.2825[a]	.2150[a]	.2034[a]	.1951[a]	

*See Appendix 7.1 for plant codes.

Samples were also taken from the pilot model at Section 6 near Bonanza. Samples were taken at four depths at each of three replications for both the Paraho processed shale and Union processed shale. The plants within the trench were planted so close originally that samples were not identified by species, since there was the potential for intermixing of roots. The root samples were treated the same as the Anvil Points samples and analysis of variance was run on the extracted root biomass. The summary results are shown in Table 7.1-2. The analysis shows that there was more root biomass in the Union processed portion of the pilot model than the Paraho processed portion. Root biomass averaged .1125 g/1000 g soil on the Union portion and .0797 g/1000g soil on the Paraho portion. Unlike the Anvil Points area there was no significant difference in root biomass with depth. With the low number of samples (3) taken at the Section 6 site and the high variability within samples, non significant results were anticipated.

7.1.4.3 Migration of Salts Studies initiated in 1979 at Anvil Points established a topsoil filled trench in a shale disposal pile. The survival of species transplanted into the soil trenches in this experiment has been monitored since 1979. Beginning in 1981, soil samples were collected from various depths in the soil trench and adjacent shale and have been analyzed chemically. The results for 1983 are reported in Table 7.1-3. Some overall trends observed in 1981 and 1982 were again evident in 1983. The pH, EC, sodium (Na), magnesium (Mg), and molybdenum (Mo), sulfates (SO_4), boron (B) and organic carbon (OC) were found to be higher in the shale samples. Mercury (Hg), and clorine (Cl), potassium (K), cadmium (Cd), calcium (Ca) and arsenic (As) showed

Table 7.1-2 Root weights (g) per 1000 grams of soil sampled at Section 6, Bonanza, Utah, June 1983. Values followed by common letters are not significantly different at test by ANOVA (F-value $\leq$ .05).

Depth	Rep 1	Rep 2	Rep 3	$\bar{X}$	S
			Paraho		
Soil surface	.0455	.2929	.0022	.1135	.1568
Mid trench soil	.1026	.0452	.0378	.0619	.0355
Trench bottom soil	.3047	.0371	.0329	.1249	.1557
Trench bottom shale	.0489	.0051	.0018	.0186	.0263
$\bar{X}$	.1254	.0951	.0187	.0797[a]	$\pm$.059
			Union		
Soil surface	.1722	.0030	.0577	.0776	.0848
Mid trench soil	.2547	.0318	.4830	.2565	.2256
Trench bottom soil	.0200	.0525	.0022	.0249	.0182
Trench bottom shale	.0223	.1988	.0513	.0908	.0946
$\bar{X}$	.1173	.0715	.1486	.1125[b]	$\pm$.0388

Table 7.1-3. Soil samples taken from Anvil Points, Colorado - June 10, 1983.

Variable	Soil (0-2 cm)	Soil (30 cm)	Soil (45 cm)	Soil (15 cm)	Shale (15 cm)	Shale (0-2 cm)	Shale (60 cm)	$\bar{x}$ Soil	$\bar{x}$ Shale	T-Value	Significance Level
pH	8.70	8.24	8.33	8.42	8.67	8.61	8.80	8.42	8.69	-2.14	.005
EC_emmhos/cm	1.7	2.8	4.8	2.7	4.4	10.3	7.6	3.0	7.4	-2.74	.025
%OC	6.9	5.8	5.4	6.0	8.2	7.9	7.9	6.0	8.0	-5.14	.005
Ca(ppm)	1923.8	3782.8	5186.2	6476.2	2593.9	1928.7	2844.1	4341.8	2455.6	1.60	N.S.*
Mg(ppm)	325.2	274.6	308.9	354.6	608.6	533.9	476.6	315.8	539.7	-5.92	.005
Na(ppm)	112.5	154.7	218.0	141.6	257.1	401.5	354.3	156.7	337.6	-4.09	.005
Cd(ppm)	<.002	<.002	<.04	<.002	<0.2	<.002	<.04	<.012	<.081	-1.33	N.S.
As(ppm)	20.4	19.5	22.0	19.8	11.6	25.0	15.2	20.4	17.3	0.93	N.S.
Mo(ppm)	<.04	<.005	<.005	<.005	<0.76	3.44	<0.80	<.014	1.67	-2.23	.005
Hg(ppm)	<.002	<.002	<.002	<.91	< .002	<.002	<.002	<.23	<.002	0.85	N.S.
K(ppm)	470.7	249.4	318.9	302.9	672.0	672.0	283.7	335.5	458.2	-1.11	N.S.
SO_4(ppm)	185.0	242.0	338.0	330.0	738.0	738.0	714.0	273.8	613.7	-3.29	.025
Cl(ppm)	7.3	4.9	5.7	6.0	5.9	5.9	4.2	6.0	5.2	1.11	N.S.
B(ppm)	8.1	4.6	4.7	5.2	11.4	11.4	9.6	5.7	9.9	-3.59	.01

* N.S. - not significant

no significant differences between soil and shale samples.

Detailed analysis of pH and EC were performed for the 1981-1983 period on the Anvil Points trenches. The summary table for pH is shown in Table 7.1-4. There is a significant increase in pH over this two year period with an overall 1981 average of 7.92 and increasing to 8.53 in 1983. This figure is still within the tolerance levels for all the species growing in the trench and it would appear that the pH will start leveling off from the current rate of approximately +.25/year. The ANOVA also showed significant differences among the depths sampled. The pH of the topsoil samples were all significantly lower than the shale samples, when data from all three years were compared. When only 1983 data were compared using ANOVA, the results differed. The pH of the topsoil surface had increased and in 1983 was not significantly different from the shale samples. The topsoil surface was also not significantly different from the other topsoil samples with the exception of the 30 cm depth.

The two-way ANOVA for EC showed that there were no significant differences between years. The 1983 average was the same as 1981 (Table 7.1-5). There were significant differences between depths with the topsoil samples having lower EC values than the shale samples. The surface shale sample was extremely high averaging 15.8 mmhos/cm^3. The topsoil EC values are well within the range of tolerance for species that would be used for reclamation.

The general trend with time appears to be an increasing salt level in the topsoil trench. This is best shown by the increase of pH from 1981 to 1983. However, another measure of salts, EC, showed no increase from 1981 to 1983. Individual salts, i.e., Na, Ca, etc. fluctuate so much that only trends could be

Table 7.1-4 pH values from different depths in the topsoil trench study at Anvil Points for the period from 1981-1983. Values followed by common letters are not significantly different as tested by ANOVA and Fisher's LSD (F-value ≤ .005, α ≤ .05)

Sample depth	1981 June $\bar{x}$	1981 October $\bar{x}$	1982 June $\bar{x}$	1983 June $\bar{x}$	1981-1983 $\bar{x}$
0-2 cm topsoil	7.90	7.85	8.08	8.60 ^{bc}	8.11^{b}
15 cm topsoil	7.41	7.69	7.78	8.35 ^{ab}	7.81^{a}
30 cm topsoil	7.52	7.64	7.76	8.25^{a}	7.80^{a}
45 cm topsoil	7.61	7.89	7.89	8.33^{ab}	7.93^{ab}
0-2 cm shale	8.72	8.70	8.55	8.70 ^{c}	8.67^{d}
15 cm shale	8.11	8.51	8.50	8.67 ^{c}	8.45^{c}
60 cm shale	8.14	8.51	8.70	8.77 ^{c}	8.53^{cd}
Average	7.92^{a}	8.11^{b}	8.18^{b}	8.53^{c}	

ANOVA Table for 1981-1983 for pH

S.O.V.	df	S.S	M.S.	F-value
Year (1)	3	4.06	1.35	18.39*
Depth (2)	6	9.41	1.57	21.40*
1 x 2	18	1.41	.08	1.10
Error	56	4.11	.07	
Total	83	18.99		

* significant at $\alpha \leq .005$.

ANOVA Table for 1983 for pH only

Depth	6	.78	.13	4.31**
Error	14	.42	.03	
Total	20	1.20		

** significant at $\alpha \leq .05$

Table 7.1-5 Electrical conductivity (EC) values sampled from different depths in the topsoil trench at Anvil Points for the period from 1981-1983. Values followed by common letters are not significantly different as tested by ANOVA and Fisher's LSD (F-value $\leq$ .01, $\alpha \leq$ .05)

Sample depth	1981 June $\bar{x}$	1981 October $\bar{x}$	1982 June $\bar{x}$	1983 June $\bar{x}$	1981-1983 $\bar{x}$
0-2 cm topsoil	4.4	3.1	1.9	1.9	2.8^{a}
15 cm topsoil	2.0	2.9	3.4	3.2	2.9^{a}
30 cm topsoil	3.0	4.4	4.8	3.0	3.8^{ab}
45 cm topsoil	3.7	7.5	5.1	5.0	5.3^{ab}
0-2 cm topsoil	16.7	14.6	17.9	14.1	15.8^{c}
15 cm shale	4.5	12.7	8.9	5.5	7.9^{b}
60 cm shale	6.2	12.5	7.2	8.1	8.5^{b}
$\bar{x}$	5.8^{a}	8.2^{a}	7.0^{a}	5.8^{a}	

ANOVA table for EC for years 1981-1983

S.O.V.	df	S.S.	M.S.	F
Years (1)	3	84.92	28.31	0.77
Depths (2)	6	1534.27	255.71	6.95*
1 x 2	18	183.38	10.19	0.28
Error	56	2060.79	36.80	
Total	83	3863.36		

* significant at $\alpha \leq .01$.

identified. These trends point to increased levels of salts in the topsoil, however, the topsoil samples were still lower than samples analyzed from the shale (Table 7.1-3).

7.1.4.4 Plant Establishment Studies Studies have been conducted since early 1976 to evaluate various techniques that can be used to establish plants in oil shale disposal areas. The information collected in 1983 from each study area includes height, cover, and survival of each planting.

A. Evaluation of Plantings at Anvil Points, Colorado The six different plantings on the shale disposal pile at Anvil Points were evaluated in June 1983. The height and cover of each living plant was recorded (Tables 7.1-6). Mortality in addition to previous observations was also noted. Two mat saltbush plants were lost during the 1983 growing season. Both were in the soil-shale microenvironment study. Three other species suffered single losses, cuneate saltbush and shadscale in the soil-shale microenvironment study area, and kochia in the flat plantings. Two plants, one greasewood and one seepweed, which were classified as dead in 1982 resprouted in 1983. The percent survival of each species at each study site for years 1979-1983 is given in Table 7.1-7. In the soil trench plantings, fourwing saltbush, western wheatgrass and greasewood show 100% survival. Shadscale and cuneate saltbush had a single mortality in the north trench and two mortalities in the south trench. Prostrate kochia and seepweed have suffered the greatest overall mortality in the two soil trenches, 67% and 60% respectively in the south trench and 50% and 40% respectively in the north trench.

The basin plantings show the highest mortality of the different

Table 7.1-6. Plant height and cover estimates. Cover estimated by counting the number of 1 dm^2 grids occupied by each plant. Cover values represent the number of grids occupied by the plant. Height is in cm. Anvil Points, Colorado. June 1983.

	NORTH SOIL TRENCH													
	ATCA Fourwing Saltbush		ATCO Shadscale		ATCU Cuneate Saltbush		AGSM Western Wheatgrass		SAVE Greasewood		KOPR Prostrate Kochia		SUFR Seepweed	
Replication	Height	Cover	Height	Cover	Height	Cover	Height	Cover	Height	Cover	Height	Cover	Height	Cover
I	68	35	34	5	14	25	64	50	85	55	M	M		
II	91	33	29	5	35	50	41	70	115	90			M	M
III	40	12	25	8	32	45	52	50	101	20	M	M		
IV	73	15	M	M	M	M	46	30	90	80			M	M
V	52	6	20	4	27	25	40	20	56	28	23	3		
VI	84	30	15	2	31	25	41	40	65	25			16	1
VII	55	3	15	2	15	12	35	28	75	35	30	15		
VIII	79	30	17	3	25	26	48	15	109	45			30	2
IX	76	20	20	5	40	36	42	10	68	30	M	M		
X	65	20	16	3	39	40	48		78	50	27	4	M	M
XI									135	45				
Average	69.1	19.3	21.8	4.1	30.0	32.7	45.7	34.3	88.8	45.7	26.7	7.3	23	1.5
Standard Deviation	14.2	10.5	6.7	2.0	9.8	11.8	8.1	18.4	24.0	22.4	3.5	6.7	0.7	---
	SOUTH SOIL TRENCH													
I	76	28	M	M	25	42	41	200	125	111	M	M		
II	80	50	20	4	M	M	52	175	125	150			M	M
III	86	23	12	1	31	30	45	50	72	25	31	50		
IV	93	60	21	6	42	22	39	25	105	60			13	1
V	88	70	28	6	24	25	45	35	102	45	M	M		
VI	34	2	16	3	29	25	29	20	87	30			15	4
VII	75	25	11	2	21	12	38	25	35	25	28	12		
VIII	95	30	15	1	M	M	37	25	102	45			18	2
IX	74	22	M	M	29	28	54	40	72	25	29	8		
X	64	14	15	3	38	30	34	10	92	55	26	6	M	M
									67	30				
Average	76.5	32.4	17.2	3.3	29.9	26.8	41.4	60.5	89.5	54.6	28.5	19.0	15.3	2.3
Standard Deviation	17.7	21.1	5.5	2.0	7.1		7.8	68.1	26.8	40.4	2.1	20.6	2.5	1.5

Table 7.1-6. (Continued).

BASIN PLANTINGS

Replication	ATCA Fourwing Saltbush Height	ATCA Fourwing Saltbush Cover	ATCO Shadscale Height	ATCO Shadscale Cover	ATCU Cuneate Saltbush Height	ATCU Cuneate Saltbush Cover	AGSM Western Wheatgrass Height	AGSM Western Wheatgrass Cover	SAVE Greasewood Height	SAVE Greasewood Cover	KOPR Prostrate Kochia Height	KOPR Prostrate Kochia Cover	SUFR Seepweed Height	SUFR Seepweed Cover
I	61	34	M	M	32	40	64	15	77	25			M	M
II	80	65	M	M	11	1	80	12	73	29			M	M
III	36	5	M	M	M	M	72	15	80	33			M	M
IV	108	130	M	M	15	15	72	3	77	40			M	M
V	M	M	M	M	M	M	M	M	25	1			M	M
Average	71.3	58.5	M	M	19.3	18.7	72.0	11.3	66.4	25.6			M	M
Standard Deviation	31.4	53.6			11.2	19.8	6.5	5.7	23.3	14.8				

FLAT PLANTINGS

I	54	15	18	4	27	20	34	1	29	5			M	M
II	103	65	30	4	34	27	38	3	40	5			34	12
III	73	26	33	12	35	28	43	2	67	10			25	5
IV	72	27	M	M	33	23	50	2	57	20			M	M
V	46	8	25	12	41	45	62	2	59	26			M	M
Average	69.6	28.2	21.5	8.0	34.0	28.6	45.4	2.0	50.4	13.2			29.5	8.5
Standard Deviation	22.0	22.0	9.8	4.6	5.0	9.7	11.0	.7	15.5	9.4				

Table 7.1-6. (Continued).

EAST FENCE

Replication	SAVE Grease-wood Height	SAVE Grease-wood Cover	ATCA Fourwing Saltbush Height	ATCA Fourwing Saltbush Cover	HAHA Siberian Salt-tree Height	HAHA Siberian Salt-tree Cover	ATCO Shad-scale Height	ATCO Shad-scale Cover	ARTR Big Sagebrush Height	ARTR Big Sagebrush Cover	ATGA Gardners Saltbush Height	ATGA Gardners Saltbush Cover
I	62	25	75	25	6	.3	30	16	Me	Me	17	24
II	27	11	32	6							13	20
III	49	26	62	28								
IV	39	20										
Average	44.3	20.5	56.3	19.7	6	.3	30	16	M	M	15.0	22.0
Standard Deviation	14.9	6.9	22.0	11.9	0	0	0	0			2.8	2.8

SOUTH FENCH

I	34	6	110	75	43	3	M	M				
II	18	4	56	22			13	2				
III	38	17	102	45			M	M				
IV	26	7	M	M			33	20				
V	37	13	40	20								
VI	48	12	M	M								
Average	33.5	9.7	77.0	40.5	43	3	23.0	11.0				
Standard Deviation	10.4	5.2	34.3	25.6	0	0	14.1	21.7				

e-grown in soil prior to transplanting, all other were grown in spent shale.
M-plant mortality
blank-no planting

Table 7.1-7. Summary of survival of plantings at Anvil Points, Colorado, 1979-1983.

South Trench Plantings

Species	Survival (%) 1979	1980	1981	1982	1983
ATCA	100	100	100	100	100
ATCO	100	90	80	80	80
ATCU	100	100	100	80	80
AGSM	100	100	100	100	100
SAVE	100	100	100	100	100
KOPR	67	67	67	67	67
SUFR	80	60	60	60	60
North Trench Plantings					
ATCA	100	100	100	100	100
ATCO	100	90	90	90	90
ATCU	100	90	90	90	90
AGSM	100	100	100	100	100
SAVE	100	100	100	100	100
KOPR	50	50	50	50	50
SUFR	100	40	40	20	40
Basin Plantings					
ATCA	100	100	100	80	80
ATCO	100	20	0	0	0
ATCU	100	80	60	60	60
AGSM	100	80	80	80	80
SAVE	100	100	100	80	100
KOPR	100	40	20	0	0
Flat Plantings					
ATCA	100	100	100	100	100
ATCO	100	100	80	80	80
ATCU	100	100	100	100	100
AGSM	100	100	100	100	100
SAVE	100	100	100	100	100
KOPR	100	60	60	60	40

Table 7.1-7. (Continued)

Demonstration Study (East Fence)

Species	Survival (%) 1979	1980	1981	1982	1983
ATCA	100	100	100	100	100
ATCO	100	100	100	100	100
ATGA	100	100	100	100	100
ARTR	100	100	0	0	0
SAVE	100	100	100	100	100
HAHA	100	100	100	100	100
Demonstration Study (South Fence)					
ATCA	83	67	67	67	67
ATCO	75	75	50	50	50
SAVE	100	100	100	100	100
HAHA	100	100	100	100	100
Soil-Shale Microenvironment Study					
ATCA	100	100	80	60	60
ATCO	100	100	100	100	80
ATCU	100	100	100	100	80
AGSM	100	100	100	100	100
ATCOR	100	100	80	80	40

establishment techniques tested on the Anvil Points shale disposal site. Greasewood (100%), fourwing saltbush, and western wheatgrass (both 80%) have the highest percentage survival, cuneate saltbush has 60% survival, and shadscale and prostrate kochia 0% survival.

The flat plantings and demonstration study area along the east fence have had no change in survival since 1981 with the exception of the loss of one prostrate kochia this year in the flat planting. Both show high survival rates for all species except big sagebrush (0%) along the east fence and prostrate kochia (40%) in the flat plantings.

The survival of species planted along the south fence as part of the demonstration study did not change from the 1981 and 1982 results. Along the south fence greasewood and Siberian salt-tree (Halimodendron halodendron) show the best survival (100%) and fourwing saltbush and shadscale the worst (67%, 50%, respectively). The soil-shale microenvironment plantings experienced significant losses in 1983. Four plants died including one shadscale, two cuneate saltbush, and one fourwing saltbush. Western wheatgrass still shows 100% survival.

A summary and analysis of the data for height and cover collected on the plantings at Anvil Points since 1979 is presented in Table 7.1-8. Several species have shown remarkable survival and growth under the various treatments. Fourwing saltbush, cuneate saltbush, western wheatgrass, and greasewood have shown the best survival and growth of the species used in the several different studies conducted at Anvil Points. Other species such as Siberian salt-tree and gardner's saltbush have shown good survival, but have not been tested as

Table 7.1-8. Summary of growth of plantings at Anvil Points, Colorado, 1979-1983. Numbers followed by different letters are significantly different at $\alpha \leq .05$ as tested by ANOVA and Fishers LSD mean separation test.

Comparison of Average Height (cm) and Cover of Plantings in South Trench

		1979	1980	1981	1982	1983	F ratio
Fourwing Saltbush	HT	26.7^{a}	35.6^{a}	56.3^{b}	66.6^{bc}	76.5^{c}	19.28**
	CVR	----	5.4^{a}	20.0^{b}	25.1^{b}	32.4^{b}	5.77**
Shadscale	HT	5.8^{a}	8.2^{a}	11.0^{a}	10.9^{a}	13.8^{a}	2.10 N.S.
	CVR	----	0.8^{a}	1.2^{ab}	2.4^{b}	2.6^{b}	3.08*
Cuneate Saltbush	HT	14.6^{a}	18.0^{a}	22.1^{a}	21.0^{a}	23.9^{a}	1.38 N.S.
	CVR	----	2.9^{a}	10.4^{ab}	16.6^{bc}	21.4^{c}	8.54**
Western Wheatgrass	HT	22.3^{b}	18.8^{ab}	15.0^{a}	29.0^{c}	41.4^{d}	26.85**
	CVR	----	0.8^{a}	5.7^{a}	17.9^{a}	60.5^{b}	5.83**
Greasewood	HT	25.5^{a}	35.9^{a}	58.8^{b}	71.0^{b}	89.5^{c}	17.37**
	CVR	----	4.7^{a}	19.5^{ab}	32.1^{b}	54.6^{c}	9.37**
Prostrate Kochia	HT	19.8^{a}	13.0^{a}	21.3^{a}	22.3^{a}	19.0^{a}	.27 N.S.
	CVR	----	2.3^{a}	7.5^{a}	10.8^{a}	15.2^{a}	.88 N.S.
Seepweed	HT	13.8^{a}	13.6^{a}	14.4^{a}	18.2^{b}	9.2^{a}	.32 N.S.
	CVR	----	$.6^{a}$	1.1^{a}	1.2^{a}	1.4^{a}	.37 N.S.

**F-ratio significant at $\alpha \leq .01$

*F-ratio significant at $\alpha \leq .05$

N.S.-non-significant

Table 7.1 - 8. (Continued)

Comparison of
Average Height (cm) and Cover
of Plantings
in
North Trench

		1979	1980	1981	1982	1983	F-ratio
Fourwing Saltbush	HT	24.1^{a}	29.9^{a}	54.7^{b}	60.8^{bc}	69.1^{c}	21.61**
	CVR	----	3.0^{a}	10.7^{b}	14.4^{bc}	20.4^{c}	8.98**
Shadscale	HT	7.5^{a}	8.5^{a}	14.8^{b}	14.1^{ab}	19.1^{b}	5.08**
	CVR	----	0.7^{a}	1.4^{a}	3.4^{b}	3.8^{b}	8.31**
Cuneate Saltbush	HT	10.3^{ab}	8.8^{a}	15.1^{ab}	16.6^{b}	25.8^{c}	7.37**
	CVR	----	2.3^{a}	8.7^{a}	21.5^{b}	28.4^{b}	13.88**
Western Wheatgrass	HT	23.7^{b}	19.9^{ab}	16.2^{a}	33.0^{c}	45.7^{d}	31.52**
	CVR	----	0.7^{a}	7.0^{a}	19.5^{b}	32.8^{c}	18.17**
Greasewood	HT	21.3^{a}	33.1^{b}	61.2^{c}	75.8^{d}	88.8^{d}	31.73**
	CVR	----	4.3^{a}	18.4^{b}	27.0^{b}	45.7^{c}	20.33**
Prostrate Kochia	HT	7.4^{a}	8.0^{a}	16.7^{a}	19.0^{a}	13.3^{a}	.61 N.S.
	CVR	----	1.0^{a}	3.3^{a}	3.7^{a}	3.7^{a}	.47 N
Seepweed	HT	16.3^{a}	6.4^{a}	9.4^{a}	12.60^{a}	9.2^{a}	.41 N.S.
	CVR	----	$.4^{a}$	$.4^{a}$	$.6^{a}$	$.6^{a}$	.15 N.S.

Table 7.1 - 8 (Continued)

Comparison of
Average Height (cm) of
Flat Plantings

		1979	1980	1981	1982	1983	F-ratio
Fourwing Saltbush	HT	27.8^{a}	36.6^{a}	60.0^{b}	63.6^{b}	69.6^{b}	5.14**
	CVR	----	2.3^{a}	11.6^{a}	14.4^{ab}	28.2^{b}	3.75*
Shadscale	HT	7.6^{a}	9.2^{a}	8.8^{a}	12.0^{a}	17.2^{a}	1.15 N.S.
	CVR	----	0.9^{a}	1.3^{a}	4.0^{a}	6.4^{a}	3.09 N.S.
Cuneate Saltbush	HT	12.8^{a}	15.2^{ab}	20.6^{b}	27.8^{c}	34.0^{d}	15.66**
	CVR	----	1.8^{a}	8.6^{a}	18.0^{b}	28.6^{c}	12.04**
Western Wheatgrass	HT	19.6^{a}	28.2^{ab}	32.2^{b}	33.4^{b}	45.4^{c}	7.92**
	CVR	----	0.5^{a}	1.2^{ab}	1.4^{bc}	2.0^{c}	5.29**
Greasewood	HT	18.0^{a}	28.4^{ab}	34.4^{abc}	43.8^{bc}	50.4^{c}	4.75*
	CVR	----	1.9^{a}	4.6^{ab}	10.4^{bc}	13.2^{c}	3.52*
Seepweed	HT	17.4^{a}	14.0^{a}	16.2^{a}	23.8^{a}	11.8^{a}	.42 N.S.
	CVR	----	0.8^{a}	2.8^{a}	4.8^{a}	3.4^{a}	.84 N.S.

Table 7.1 - 8 (Continued)

Comparison of
Average Height (cm) and Cover
of
Basin Plantings

		1979	1980	1981	1982	1983	F-ratio
Fourwing Saltbush	HT	27.2^{a}	33.8^{ab}_{a}	63.0^{bc}_{a}	65.0^{bc}_{a}	57.0^{b}_{a}	3.47*
	CVR	----	4.6^{a}	19.0^{a}	41.4^{a}	46.8^{a}	1.76 N.S.
Shadscale	HT	5.2^{b}	1.8^{ab}	0^{a}	0^{a}	0^{a}	6.60**
	CVR	----	$.2^{a}$	0^{a}	0^{a}	0^{a}	1.00 N.S.
Cuneate Saltbush	HT	9.0^{a}	9.6^{a}_{a}	7.8^{a}_{a}	4.8^{a}_{a}	11.6^{a}_{a}	.41 N.S.
	CVR	----	3.6^{a}	3.0^{a}	5.0^{a}	11.2^{a}	.62 N.S.
Western Wheatgrass	HT	22.0^{a}	18.8^{a}_{a}	40.2^{a}_{a}	40.6^{a}_{a}	57.6^{a}_{b}	2.61 N.S.
	CVR	----	$.4^{a}$	1.5^{a}	4.0^{a}	9.0^{b}	5.03 *
Greasewood	HT	18.2^{a}	28.4^{ab}_{a}	47.0^{bc}_{ab}	56.2^{c}_{bc}	66.4^{c}_{c}	6.70**
	CVR	----	2.7^{a}	11.3^{ab}	17.2^{bc}	25.6^{c}	4.86*
Seepweed	HT	31.2^{a}	14.0^{a}_{a}	9.0^{a}_{a}	8.2^{a}_{a}	0^{a}_{a}	2.76 N.S.
	CVR	----	1.1^{a}	4.4^{a}	$.8^{a}$	0^{a}	.73 N.S.

extensively as the other species. Big sagebrush and seepweed have shown the poorest survival.

B. Pilot Model-Plant Survival and Growth on Union and Paraho Processed Shale Disposed shale from two processes, Paraho and Union, were compared in the pilot model with plants growing in a topsoil filled trench at the Section 6 study site. In the fall of the sixth growing season (1983) 70% of the species planted were still surviving in the portion of the pilot model containing the Union processed shale while only 50% were surviving in the Paraho processed shale. This experiment was terminated in 1983 because the transplants currently are too close together causing a great deal of root intermingling and competition which would confound the effects of the types of processed shale and because soil samples were taken at various depths and locations in the trench to assess salt movement.

7.1.4.5 Microbiology and Stabilization of Topsoil Storage Pile

Long-term stockpiling can reduce microbial activities in topsoils making them less suitable as plant growth media (Rives et al., 1980; Williams et al., 1981). Many soil microorganisms are directly or indirectly dependent on living plants for their existence, and the absence of plant roots in much of the stored soil is partly responsible for the loss of these organisms. Soil microbial populations in stockpiles could be maintained to some extent by minimizing the duration of storage, and/or by establishing and maintaining appropriate plant cover on the storage piles. Therefore, seeding of soil stockpiles is not only valuable for erosion control and stockpile stabilization, but also for the maintenance of important soil biological characteristics. The purpose of this

study is to evaluate the effect of seeding on the microbiological activity of stockpiled topsoil through time.

The design and installation of the topsoil stockpile study was completed October 12, 1983. The study is located on the small topsoil pile near the mine services building at the plant site. The treatments consist of two different seed mixes (shallow and deep rooted species, Table 7.1-9), two fertilizer regimes (no fertilizer and 85 lbs. ammonium nitrate/acre) with three replications of each laid out in completely randomized 9 m x 9 m plots (Figure 7.1-2). Three replicates of the control treatment were also identified.

The stockpile had been seeded in the fall of 1982, but the seedling survival was very poor. The plots were flagged in and then lightly rototilled to remove any plants seeded previously and to prepare a suitable seedbed for planting. The seed was hand broadcasted and then the plots were raked to encourage seed burial. Each plot was covered with a straw mulch (a rate of 1.5 tons/acre) which was tacked at a rate of 240 lbs. of Terra Tak AR/acre so the straw would not blow off. The plots will be fertilized in spring after germination has occurred. The study plots prior to mulching are shown in Figure 7.1-3.

In June 1984 and October 1984, soils from the research plots will be sampled at a variety of depths and analyzed using most probable number techniques to determine profiles of mycorrhizal infection potential. These values will be compared to those obtained from soils sampled in the control treatments. Results from these and subsequent sampling will allow design of stockpile maintenance procedures that will maximize the thickness of the root

Table 7.1-9. Seed mixes used on topsoil pile soil microbiology study.

Seed Mix A

Deep rooted plants

Species/Lot #	Rate (lbs/acre)
ARTR/846	1
ATCA/2208	3
ATCO/888	3
CELA/2248	2
CHNA/2022	1
MESA - Ladak/1980	2
PUTR/1627	3
AGSM/2212	2
AGEL/2297	3
HEBO/2330	3
	23 lbs/acre

Seed Mix B

Shallow rooted plants

Species/Lot #	Rate (lbs/acre)
ERUM/3011	2
LILE/1786	2
SPGR/1632	1
AGDA - Critana/1430	2
AGIN - Greenar/2075	3
AGSM - Arriba/2212	2
AGTR2 - Luna/1188	3
BOGR/1984	1
HIJA/1939	2
ORHY/2377	2
	20 lbs/acre

Figure 7.1-2. Design and layout of seeding and fertilizer treatments on topsoil storage pile adjacent to mining services building at the plant site. Plots approximately 9m x 9m.

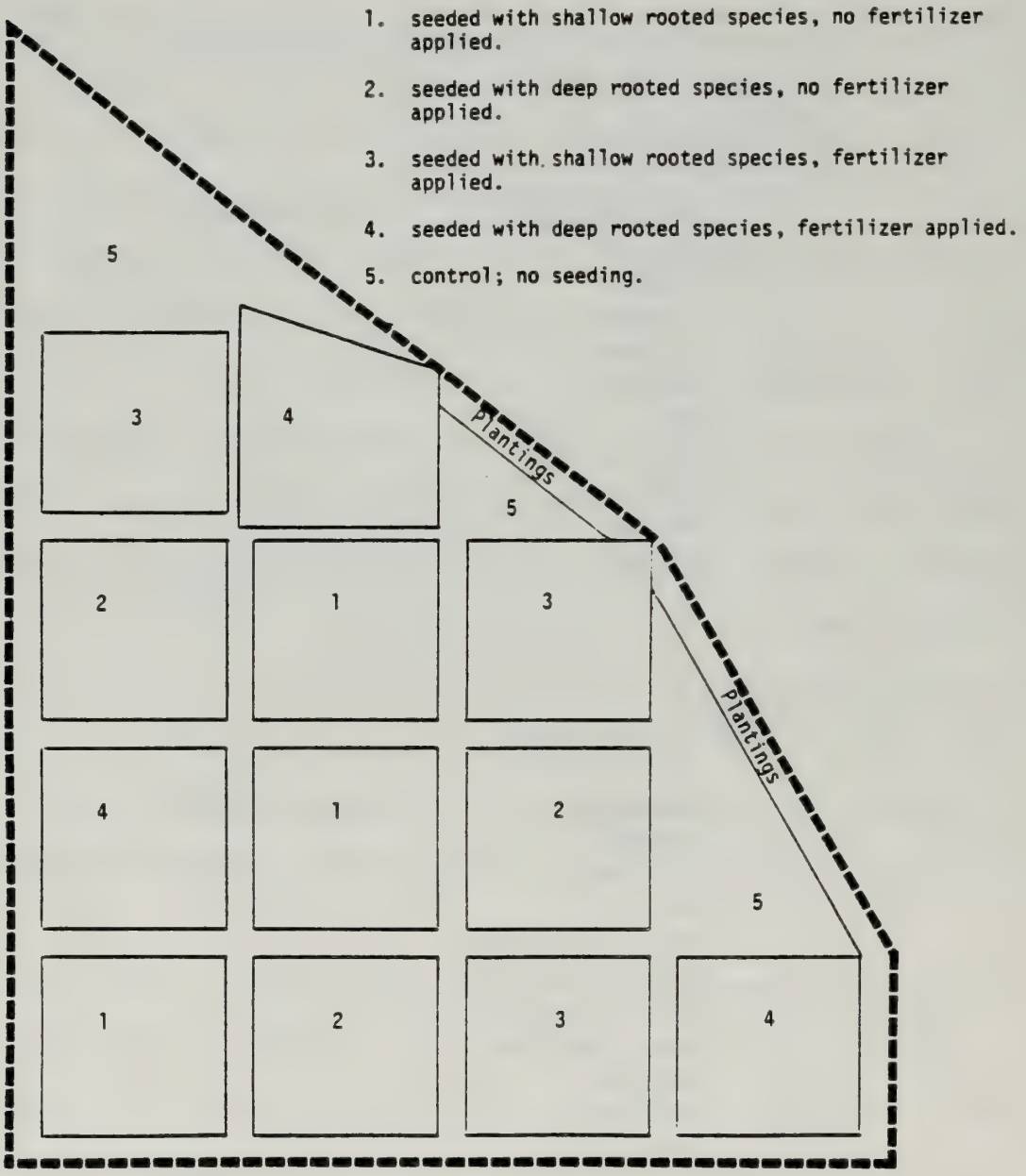
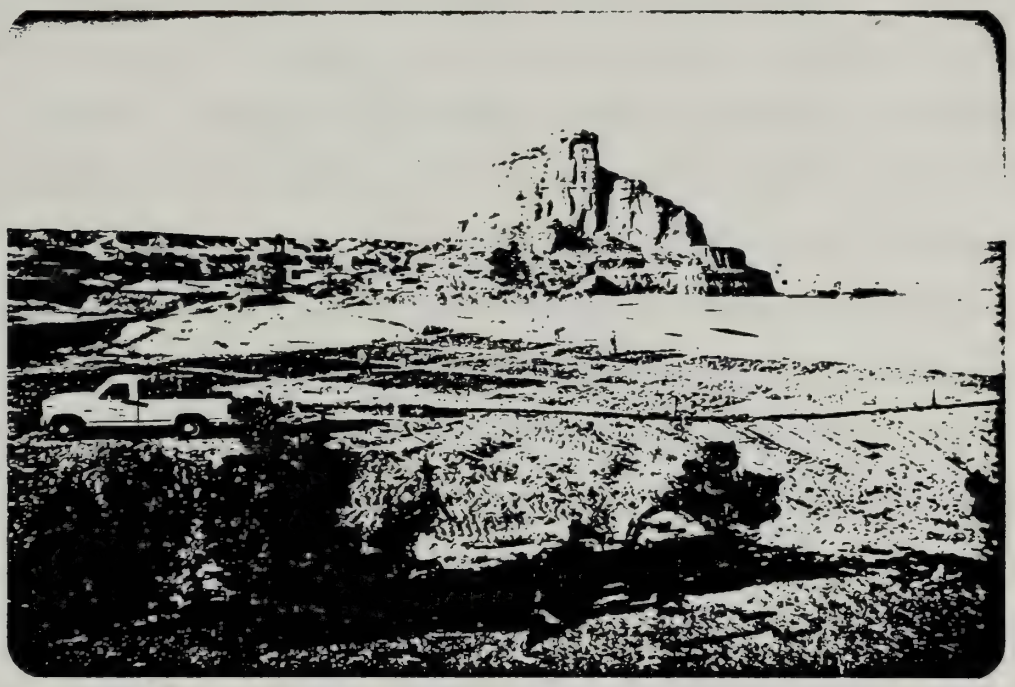


Figure 7.1-3 Photo showing the design and initial establishment of test plots on the topsoil storage pile near the mine services building. Photo taken October 1983.



zone, maximize populations of VAM fungi in the root zone, and thus maintain the highest populations of VAM fungi in the stockpile as a whole.

7.1.4.5 Interseeding and Interplanting Existing Shrub Vegetation As a means of increasing the wildlife carrying capacity of existing shrub dominated vegetation, interseeding and/or interplanting has been suggested. A study was established in October 1981 to test the hypothesis that scattered interplantings of container grown plants could survive and increase community diversity and productivity. A corollary hypothesis of the study tested direct seeding (drilled and broadcast) to increase diversity and productivity.

The study was established inside the Section 6 research exclosure south of the gate. Four replications, two in sites with minimal understory plants and two in areas with dense understory of cheatgrass (Bromus tectorum), were seeded and transplanted. The species transplanted included Gardner saltbush, fourwing saltbush, rubber rabbitbrush, and Wyoming sagebrush (Artemisia tridentata wyomingensis).

The area has been monitored annually and survival in October 1983 (two years after establishment) is shown in Table 7.1-10. Only one species, sagebrush, of the four planted was still surviving and no seedlings were found in the seeded area in 1983. Sagebrush had twelve plants surviving (46%) on the site without annual plant cover and six (23%) on the site with a heavy annual plant understory. Height of the surviving sagebrush on the plots with high annual cover averaged 16.0 cm compared to 13.5 cm in June of 1982. Height of sagebrush on plots without high annual cover averaged 12.5 cm compared to 11.9 cm in June 1982. The surviving plants did show some growth, however, this was

Table 7.1-10. Summary of percentage survival of transplants for the Interplanting/Interseeding study. Section 6, June 1982 - October 1983.

		% SURVIVAL							
		Sites w/o Annual Plant Cover				Sites with Annual Cover			
Species	No. Planted	June 82	Oct. 82	June 83	Oct. 83	June 82	Oct. 82	June 83	Oct. 83
ATGA	26	15	0	4	0	4	0	0	0
ATCA	19	17	21	5	0	58	0	0	0
CHNA	26	17	0	0	0	0	0	0	0
ARTR	26	62	77	58	46	46	31	31	23

very slight. Given the favorable growing conditions of 1983, the small increase in growth was unexpected.

Since the failure of the interseeding and interplanting was based partially on the pressure exerted by an abnormally high rabbit population, the experiment was reinitiated in October of 1983 at the same study site. Alterations in the study design were made to exclude herbivores. Fencing of the interseeded areas was added as a treatment as was placement of Vexar™ tubing around one half of the transplants. The experimental design is shown in Figure 7.1-4.

The transplants included four species, fourwing saltbush, sagebrush, rabbitbrush and shadscale. Twenty plants of each species were planted in each subplot (10 with Vexar™, 10 without Vexar™). The plants were planted by hand and watered in using .3 liters of water per plant. The soil was moist at the time of planting due to earlier storms. The height of each plant was recorded for later comparisons. The seeded areas were hand broadcasted and drill seeded using a hand pushed belt seeder. The seed mix and rates are shown in Table 7.1-11.

The area was revisited 3 days following planting. The transplants that did not have the Vexar™ treatments had been severely grazed with the exception of sagebrush. Many had been clipped at ground level and may not resprout. The Vexar™ appeared to be very worthwhile in deterring herbivores and would be very cost effective if planting is going to be done in areas with high rodent populations.

To document the effect of rodents on transplant establishment, the survival of the transplants was recorded on November 2, 1983. The results are reported

Figure 7.1-4. Design and layout of interplanting and interseeding study at Section 6, Bonanza, Utah.

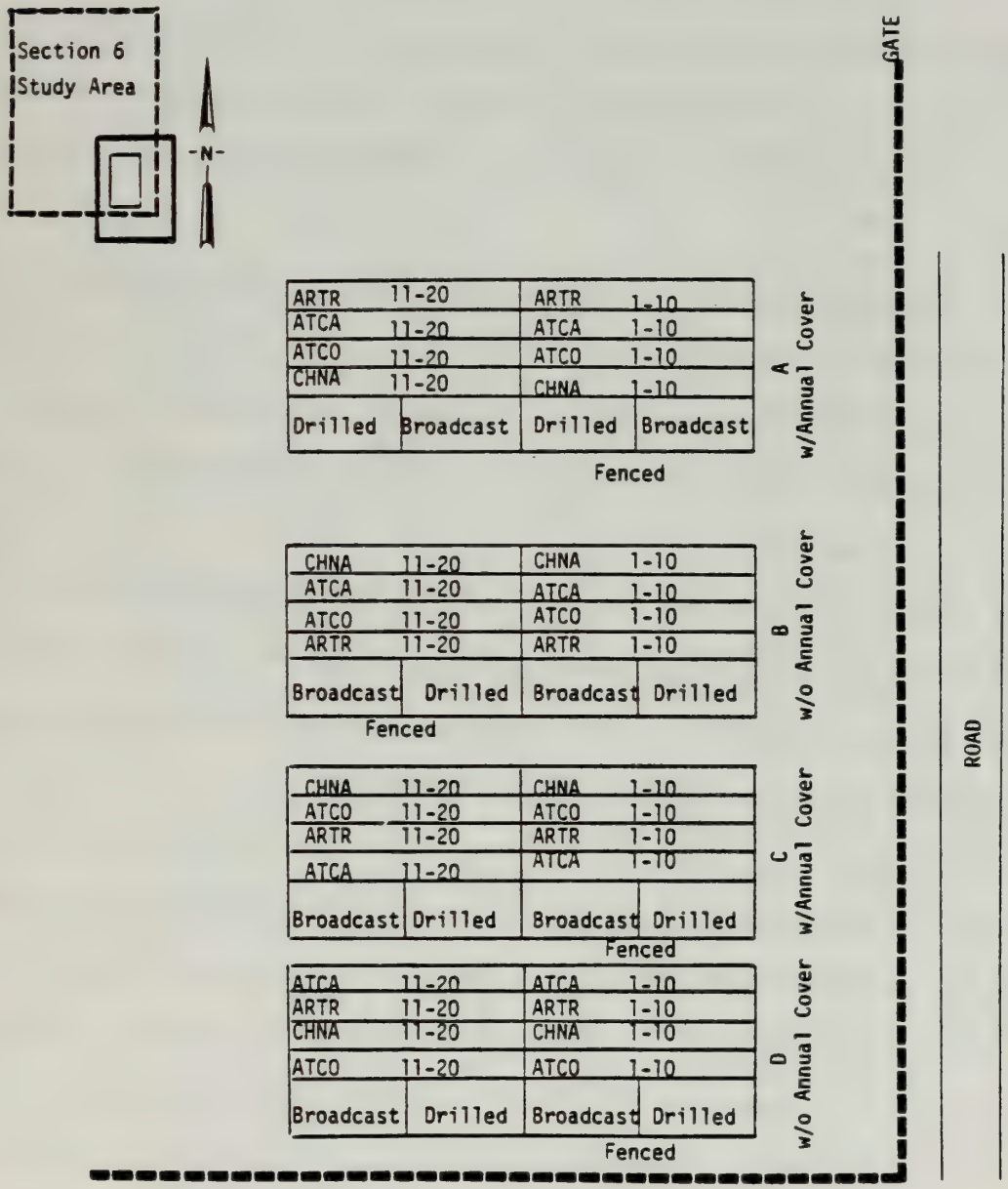


Table 7.1-11. Seed mix used for interseeding study at Section 6, Bonanza, Utah.

Seed Mix

	Species/Lot #	Rate
Shrubs:	ARTR/846	.5
	ATCA/2208	1.5
	ATCO/ 888	1.5
	CELA/2248	1
	CHNA/2022	.5
	PUTR/1627	1.5
Forbs:	ERUM/3011	1
	HEBO/2330	1.5
	LILE/1786	1
	MESA-Ladak/1980	1
	SPGR/1632	.5
Grasses:	AGDR-Critana/1430	1
	AGEL/2297	1.5
	AGIN-Greenar/2075	1.5
	AGSM-Arriba/2212	1
	AGTR2-Luna/1188	1.5
	BOGR/1984	.5
	HIJA/1939	1
	ORHY/2377	1
		20.5 PLS lbs/acre

in Table 7.1-12. Of the 40 plants of each of the four species planted without Vexar, only four sagebrush plants were considered healthy. All others were grazed either slightly or to ground level, completed defoliated, or extirpated.

7.1.4.7 Greenhouse Studies of Circular Grate Processed Shale Properties Two portions of the greenhouse studies of circular grate processed shale were not totally completed for the 1982 Final Report. A final analysis of these portions follows.

A. Leachate Experiment on Circular Grate Processed Oil Shale Leaching studies were initiated in October 1982. The purpose was to evaluate the effects of leaching on the chemical properties of circular grate processed shale, especially with regard to those water quality parameters important for plant growth.

The predictive capability of such studies are often limited by a number of factors. Oil shales are often highly saline, highly alkaline, with sulfate ions in either the runoff or leachate (McKell et al., 1979; Schmehl and McCaslin, 1979; Ward et al., 1971). Electrical conductivity values may commonly range from 9.0 to 22.0 mmhos/cm (Schmehl and McCaslin, 1973) for processed shales evaluated as a saturation extract or 9.8 to 22.0 mmhos/cm for 1:1 extracts of Paraho processed shales. Due to complex solubility relationship existing in shale water systems, comparisons between values reported by different researchers are difficult. These are further compounded by differences in methodology, including sieving, extraction procedures, and analytical techniques.

Numerous other problems are inherent which complicate efforts to analyze

Table 7.1-12. Interplanting preliminary results 1983, Section 6, Bonanza, Utah. Tubepak[R] seedlings planted on October 11, 1983. Survival taken on November 2, 1983.

Site A w/Annual Plant Cover

Species No.	Ht.(cm) 10/11/83	*Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83
ARTR-1	23		ATCA-1	29		ATCO-1	21	T	CHNA-1	14	
ARTR-2	25		ATCA-2	41		ATCO-2	19	T	CHNA-2	14	
ARTR-3	31		ATCA-3	23		ATCO-3	14		CHNA-3	14	
ARTR-4	26		ATCA-4	17		ATCO-4	12	T	CHNA-4	20	
ARTR-5	24		ATCA-5	35		ATCO-5	22	T	CHNA-5	12	
ARTR-6	22		ATCA-6	19		ATCO-6	22		CHNA-6	22	
ARTR-7	15	T	ATCA-7	16		ATCO-7	20		CHNA-7	15	
ARTR-8	28		ATCA-8	43		ATCO-8	19		CHNA-8	14	
ARTR-9	25		ATCA-9	31		ATCO-9	10	T	CHNA-9	25	
ARTR-10	24		ATCA-10	22		ATCO-10	24		CHNA-10	21	E
					Without Vexar tubeing						
ARTR-11	19	M	ATCA-11	26	S	ATCO-11	14	S	CHNA-11	23	M
ARTR-12	22	S	ATCA-12	31	M	ATCO-12	11	S	CHNA-12	13	M
ARTR-13	21	M	ATCA-13	33	M	ATCO-13	19	M	CHNA-13	18	M
ARTR-14	27	E	ATCA-14	20	E	ATCO-14	15	S	CHNA-14	21	M
ARTR-15	28	E	ATCA-15	27	S	ATCO-15	18	S	CHNA-15	19	M
ARTR-16	21	S	ATCA-16	38	M	ATCO-16	13	S	CHNA-16	20	M
ARTR-17	24	S	ATCA-17	26	S	ATCO-17	14	E	CHNA-17	20	M
ARTR-18	24	S	ATCA-18	26	M	ATCO-18	11	E	CHNA-18	21	M
ARTR-19	21	E	ATCA-19	26	E	ATCO-19	22	S	CHNA-19	19	M
ARTR-20	26	M	ATCA-20	30	S	ATCO-20	14	M	CHNA-20	22	M

* G = signs of grazing evident
T - evidence of transplant stress
Blank - alive and appear healthy
M - no evidence of tubeling, grazed to ground level
S = stem only - completely defoliated
E - extirpated

Table 7.1-12. (Continued).

Site B w/o Annual Plant Cover

Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83
ARTR-1	18		ATCA-1	21		ATCO-1	16		CHNA-1	23	
ARTR-2	19		ATCA-2	24		ATCO-2	20		CHNA-2	19	G
ARTR-3	18		ATCA-3	25		ATCO-3	17		CHNA-3	16	
ARTR-4	12		ATCA-4	27		ATCO-4	17		CHNA-4	15	
ARTR-5	17		ATCA-5	19		ATCO-5	17	T	CHNA-5	23	
ARTR-6	13		ATCA-6	27		ATCO-6	15	T	CHNA-6	16	
ARTR-7	21		ATCA-7	20		ATCO-7	16	T	CHNA-7	18	
ARTR-8	22		ATCA-8	19		ATCO-8	18	T	CHNA-8	13	
ARTR-9	23		ATCA-9	13	G	ATCO-9	16	T	CHNA-9	19	
ARTR-10	23		ATCA-10	23		ATCO-10	22	T	CHNA-10	18	
ARTR-11	17	M	ATCA-11	33	S	ATCO-11	19	S	CHNA-11	25	M
ARTR-12	23	M	ATCA-12	15	S	ATCO-12	18	S	CHNA-12	9	M
ARTR-13	31	S	ATCA-13	11	S	ATCO-13	19	M	CHNA-13	11	M
ARTR-14	23		ATCA-14	31	S	ATCO-14	8	M	CHNA-14	21	M
ARTR-15	26	M	ATCA-15	28	M	ATCO-15	21	M	CHNA-15	20	M
ARTR-16	19	M	ATCA-16	37	S	ATCO-16	17	S	CHNA-16	21	S
ARTR-17	13	M	ATCA-17	26	M	ATCO-17	16	M	CHNA-17	10	M
ARTR-18	28	S	ATCA-18	22	S	ATCO-18	23	M	CHNA-18	18	M
ARTR-19	28	S	ATCA-19	30	M	ATCO-19	12	S	CHNA-19	6	M
ARTR-20	26	M	ATCA-20	32	S	ATCO-20	23	S	CHNA-20	23	M

Table 7.1-12. (Continued).

Site C w/Annual Plant Cover

Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83
ARTR-1	18		ATCA-1	21		ATCO-1	16		CHNA-1	23	
ARTR-2	19		ATCA-2	24		ATCO-2	20		CHNA-2	19	G
ARTR-3	18		ATCA-3	25		ATCO-3	17		CHNA-3	16	
ARTR-4	12		ATCA-4	27		ATCO-4	17		CHNA-4	15	
ARTR-5	17		ATCA-5	19		ATCO-5	17	T	CHNA-5	23	
ARTR-6	13		ATCA-6	27		ATCO-6	15	T	CHNA-6	16	
ARTR-7	21		ATCA-7	20		ATCO-7	16	T	CHNA-7	18	
ARTR-8	22		ATCA-8	19		ATCO-8	18	T	CHNA-8	13	
ARTR-9	23		ATCA-9	13	G	ATCO-9	16	T	CHNA-9	19	
ARTR-10	23		ATCA-10	23		ATCO-10	22	T	CHNA-10	18	
ARTR-11	21	M	ATCA-11	26	M	ATCO	14	S	CHNA-11	22	M
ARTR-12	25	M	ATCA-12	26	E	ATCO	11	E	CHNA-12	18	M
ARTR-13	24	M	ATCA-13	16	M	ATCO	20	S	CHNA-13	17	E
ARTR-14	22	E	ATCA-14	30	S	ATCO	11	M	CHNA-14	19	M
ARTR-15	21	M	ATCA-15	27	S	ATCO	16	M	CHNA-15	14	E
ARTR-16	20	M	ATCA-16	30	E	ATCO	14	M	CHNA-16	13	M
ARTR-17	23	M	ATCA-17	25	S	ATCO	16	S	CHNA-17	14	M
ARTR-18	16	E	ATCA-18	9	S	ATCO	28	S	CHNA-18	9	M
ARTR-19	19	S	ATCA-19	13	M	ATCO	18	M	CHNA-19	14	M
ARTR-20	20	S	ATCA-20	17	M	ATCO	21	E	CHNA-20	25	E

Table 7.1-12. (Continued).

Site D w/o Annual Plant Cover

Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83	Species No.	Ht.(cm) 10/11/83	Status 11/2/83
ARTR-1	23		ATCA-1	16	G	ATCO-1	23		CHNA-1	15	
ARTR-2	25		ATCA-2	19	G	ATCO-2	23		CHNA-2	18	
ARTR-3	24		ATCA-3	30		ATCO-3	17		CHNA-3	19	G
ARTR-4	20		ATCA-4	20		ATCO-4	16	T	CHNA-4	13	
ARTR-5	22		ATCA-5	14		ATCO-5	19		CHNA-5	15	
ARTR-6	24		ATCA-6	19		ATCO-6	16		CHNA-6	14	
ARTR-7	20		ATCA-7	26		ATCO-7	28		CHNA-7	21	
ARTR-8	20		ATCA-8	14	G	ATCO-8	17		CHNA-8	21	
ARTR-9	22		ATCA-9	14		ATCO-9	21		CHNA-9	19	
ARTR-10	23		ATCA-10	17	G	ATCO-10	13		CHNA-10	14	
ARTR-11	22	S	ATCA-11	20	M	ATCO-11	16	M	CHNA-11	23	S
ARTR-12	20	M	ATCA-12	29	M	ATCO-12	13	M	CHNA-12	25	M
ARTR-13	16	S	ATCA-13	18	M	ATCO-13	16	M	CHNA-13	17	M
ARTR-14	21	S	ATCA-14	21	M	ATCO-14	22	M	CHNA-14	18	M
ARTR-15	21	M	ATCA-15	18	M	ATCO-15	20	M	CHNA-15	12	M
ARTR-16	27		ATCA-16	23	M	ATCO-16	19	M	CHNA-16	24	M
ARTR-17	29	G	ATCA-17	13	M	ATCO-17	17	M	CHNA-17	24	M
ARTR-18	25	M	ATCA-18	32	S	ATCO-18	22	M	CHNA-18	17	M
ARTR-19	23		ATCA-19	19	S	ATCO-19	18	M	CHNA-19	17	M
ARTR-20	22	M	ATCA-20	26	S	ATCO-20	15	M	CHNA-20	13	M

salt-release potentials of spent shale. Basically, processed shales vary widely between lithologic units and locations. They may also exhibit a wide range of properties due to variations in retort procedures including temperature and particle size of the feedstock disposal methods.

Despite these limitations, research can provide information on the quality of processed shale for plant growth. The leachate study being conducted by NPI provides an assessment of the salt-release potential of the circular grate material.

In previous studies (Fransway and Wagenet, 1981) it was found that "...if an accurate laboratory assessment of water soluble salts and ions for field situations is wanted, unsieved shale should be used." For these and related practical reasons, unsieved shale material was used for this study. Furthermore, those researchers found that "the readily soluble and mobile nature of the salts, as demonstrated by the continuous ponding experiments, indicated a need to examine the behavior of these salts under conditions more reasonably approximating a field case." In their studies, large pulses of water apparently resulted in a much deeper wetting of the processed shale profiles. These findings guided the design on the leachate experiment.

Four leaching columns of approximately 120 cm in depth were packed with unsieved, circular grate processed shale to a bulk density between 1.28 and 1.40 g/cm^3. Glass wool was placed between the shale and the bottom of the column to facilitate filtering of finer shale particles transported through the leaching. Due to a limited supply of material, replications in the levels of watering were not possible. Continuous ponding with distilled water was repeated on all four

columns.

The pH was determined using a 1 to 1 soil:water extract and then measured on a Corning model 125 pH meter. A saturation extract was used to measure EC and Ca, Mg, As and K were estimated using atomic absorption analysis with an ammonium acetate extractable. The sodium absorption ratio (SAR) was determined following the techniques of Richards et al (1954).

Analyses of the leachate from the first pore volume showed substantial amount of salts present. The sodium absorption ratio, pH and EC of the leachate also reflect the increase in the amount of salts being leached with only one pore volume. The amount of Mg, Na, K in the second pore volume dropped dramatically (Table 7.1-13). Calcium was the only cation that did not decrease with increasing leaching but actually increased from 103 ppm to 151 ppm. The third pore volume was generally similar to the second with lower Mg, Na, K readings and higher Ca values. The EC dropped substantially in the third pore volume from 5.21 to 1.68. pH showed a substantial drop from the first to the second pore volume 7.74 to 4.78 and then went back up in the third pore volume to 5.89. These values are all above the initial pH of the distilled water used (2.9) which shows salts are still being leached out. Total cations also remain at approximately 600 ppm through pore volumes 2 and 3 indicating that salts are still present.

These results pertaining to the suitability of the material for supporting plant growth are preliminary in nature, yet reveal distinct trends with respect to the chemical release patterns of the shale. The shale matrix is dominated by sodium, as evidenced in the data of Table 7.1-13. The release of calcium,

Table 7.1-13. Chemical Analysis of the Circular Grate Leachate Trials.

Property	Cylinder	Pore Volume 1	2	3	Unleached
Ca (ppm)	1	75	139	---	104
	2	100	140	153	120
	3	127	141	167	117
	4	109	146	133	
	Ave.	103	142	151	114
Mg (ppm)	1	62	6	---	
	2	91	5	10	549
	3	81	3	5	524
	4	88	3	5	538
	Ave.	81	4	7	537
Na (ppm)	1	1041	506	---	
	2	894	314	475	4413
	3	606	342	421	5395
	4	990	397	385	4980
	Ave.	883	390	427	4929
pH	1	7.23	5.47	---	10.34
	2	7.22	5.37	6.34	10.31
	3	7.24	4.03	6.65	10.33
	4	8.03	4.23	4.70	
	Ave.	7.74	4.78	5.89	10.33

Property	Cylinder	Pore Volume 1	2	3	Unleached
K (ppm)	1	100	58	---	105
	2	94	57	40	99
	3	95	58	31	112
	4	81	51	44	
	Ave.	90	56	38	105
Total Cations (ppm)	1	1278	709	---	
	2	1179	516	678	5171
	3	909	544	524	6138
	4	1268	597	567	5747
	Ave.	1159	592	623	5685
EC ($mmhos/cm^3$)	1	4.96	5.00	---	10.51
	2	4.91	5.45	1.65	10.12
	3	5.24	5.15	1.40	10.85
	4	4.47	5.25	2.00	
	Ave.	4.90	5.21	1.68	10.49
SAR.	1	21.5	11.4	---	38.24
	2	15.6	7.1	10.0	47.35
	3	20.6	7.8	8.8	43.27
	4	17.1	8.9	8.9	
	Ave.	18.7	8.8	9.2	42.95

magnesium, and potassium was at levels well within the tolerances of native species, however, sodium levels and especially the sodium absorption ratio are quite high even after three pore volumes of leaching.

Therefore, in light of the preliminary nature of the study and the limited amount of shale material provided, certain findings can be summarized as follows:

- The physical matrix of the shale is dominated by sodium ions, which are readily released during leaching in laboratory columns.
- The majority of the readily leached cations are removed during the first pore volume of water applied.
- High sodium levels persist in subsequent leachings through three pore volumes of water applied, suggesting either deleterious levels, physical impairment to soil-water conductivity, or both as accompanying phenomena.

B. Seedling Survival and Growth on Circular Grate Processed Shale The greenhouse transplant experiment was designed to screen various plant species for growth and survival in circular grate processed shale. The advantage to laboratory screening is that it gives quick results for relatively little cost. These results can then be useful for designing field test plot studies.

Twelve species consisting of five grasses, four forbs, and three shrubs were selected to monitor survival and growth in circular grate processed shale. The experimental design called for 20 individuals of each species which served as the replications. Seedlings were germinated in a standard nursery mix in a seedling tray. Seedlings were then transplanted with the soil plug into a cell which contained the processed shale. Transplanting occurred when the first true leaf had formed. The experiment was initiated in November 1982 and

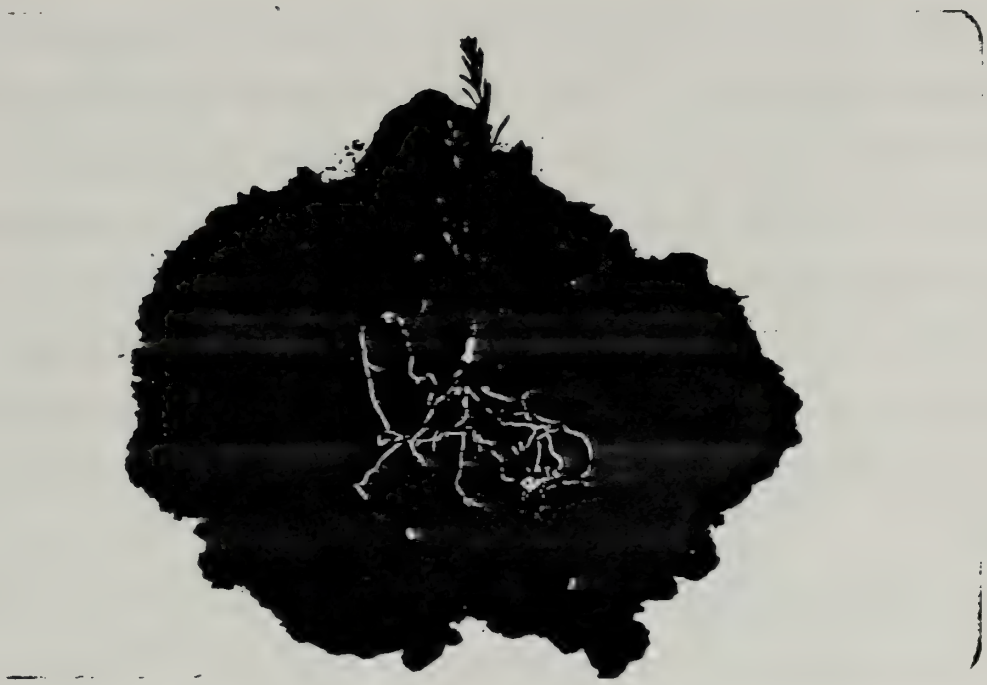
transplanting into the shale began in December 1982 and ended on April 11, 1983. Transplants were watered daily or every other day depending on the shale moisture content. Water volumes were small to avoid leaching. The intent of the study was to optimize all factors for growth except for the soil media which was processed shale. Any adverse growth responses such as micronutrient deficiencies or poor root penetration could then be attributable directly to the shale. After six weeks of growth in processed shale, several transplants were excavated to evaluate root growth. The roots were found throughout the shale material (Figure 7.1-5); some had even grown completely through the shale and out of the bottom of the pots.

Complete data was obtained on 10 species and partial data on two species. The two globemallow species (Sphaeralcea ambigua and S. munroana) have dormancy requirements which were difficult to break within the time period of the experiment as well as low viability of the seed.

Percent survival was sampled on all the species tested. All the grass and shrub species had 100% survival (Table 7.1-14). Utah sweetvetch (Hedysarum boreale) and Lewis flax (Linum lewisii) had 86% and 95% survival respectively. The other two Sphaeralcea species from which incomplete data were obtained each had 100% survival, although only six and five individuals were transplanted.

Growth of the transplants was obtained by subtracting plant height (mm) at transplant time from plant height after six weeks of growth in oil shale. Four of the five grasses, Western wheatgrass (107 mm), Indian ricegrass (Oryzopsis hymenoides) (86 mm), Crested wheatgrass (A. cristatum) (59 mm), and Russian wildrye (Elymus junceus) (55 mm), and significantly greater growth than the

Figure 7.1-5.



Roots of Linum lewisii were found growing throughout the circular grate processed shale at the end of the six week test.

Figure 7.1-6.

One of the six growth seedlings flats illustrating the general performance of the selected species in a randomized design. All species illustrated have grown for at least six weeks in the circular grate material.

other species tested. Lewis flax (25 mm), Fourwing saltbush (17 mm), greasewood (Sarcobatus vermiculatus) (15 mm), Needle and thread grass (Stipa comata) (11 mm), Utah sweetvetch (5 mm), and sagebrush (4 mm), all showed limited growth (Figure 7.1-6); however, only H. boreale showed major signs of stress or nutrient deficiencies at the end of the six-week period (Figure 7.1-7). Grasses are normally faster growing than the shrubs or forbs. This is due in part to the larger seed size of the grasses, thus the greater nutrient reserve which allows for rapid initial growth. Forbs and shrubs appeared to have very similar growth.

The results of this study indicate that Utah sweetvetch, sagebrush, and needle and thread grass are not very suitable for growth directly into shale and probably should be eliminated from future experimental growth testing. The results also demonstrate that plants can grow in circular grate processed shale and that roots penetrate the shale and do not show any abnormal changes.

Following the completion of the experiment, fertilizer applications were added of macro and micro-nutrients on two of the six flats, since many species showed symptoms of nutrient deficiencies. After one week, growth and greening on the treated plants were visually detectable. Although quantitative data were not taken, it appears that fertilization may be very important for long-term growth of plants in circular grate processed shale.

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Table 7.1-14. The growth of 12 species into circulate grate processed shale after 6 weeks. Each species was replicated 20 times.

	Growth (mm)																
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Agropyron cristatum	12	64	83	79	62	56	59	4	63	77	50	79	53	108	47	65	76
A. smithii	70	133	161	118	104	54	147	42	102	127	124	123	133	78	81	93	85
Elymus junceus	76	19	48	82	46	33	42	25	31	34	21	55	62	62	51	60	83
Oryzopsis hymenoides	60	91	91	61	91	108	63	57	147	91	39	110	115	53	186	54	103
Stipa comata	-15	21	26	2	2	2	36	-10	14	12	5	5	20	-5	11	18	18
Hedysarum boreale	8	15	M	M	-4	-6	-3	M	-2	8	20	3	-16	-12	-2	11	20
Linium lewisii	41	30	15	25	34	4	8	31	M	33	39	23	20	28	44	13	7
Sphaeralcea ambigua	15	10	6														
S. munroana	10	2	4	2	3	2											
Atriplex canescens	49	12	28	35	45	25	4	16	15	21	6	24	3	-8	25	21	2
Artemisia tridentata	2	4	0	-4	0	4	6	1	4	8	-8	6	2	8	2	3	24
Sarcobatus vermiculatus	17	10	13	12	2	2	14	19	-7	16	18	22	31	8	19	17	32

Species	18	19	20	21	22	Mean*	% Survival
Agropyron cristatum	35	35	76			59(d)	100
A. smithii	108	132	124			107(f)	100
Elymus junceus	105	86	71			55(d)	100
Oryzopsis hymenoides	60	73	69			86(e)	100
Stipa comata	26	24	0			11(a,b)	100
Hedysarum boreale	6	-9	39	-14	33	5(a,b)	86
Linium lewisii	34	22	25			25(c)	95
Sphaeralcea ambigua							
S. munroana							
Atriplex canescens	14	5	4			17(b,c)	100
Artemisia tridentata	10	-2	0			4(a)	100
Sarcobatus vermiculatus	4	27				15(a,b,c)	100

*Species sharing the same letter in parentheses are not significantly different.

M - mortality

Figure 7.1-7.

Hedysarum boreale indicating stress as shown about the leaves (pale green in color) after 113 days in circulate grate processed oil shale.

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Appendix 7.1

U.S. Forest Service Code of Plant Names

Codes	Common Name	Species
AGCR	Fairway wheatgrass	Agropyron cristatum
AGDA	Thickpike wheatgrass	A. dasystachyum
AGEL	Tall wheatgrass	A. elongatum
AGIN	Intermediate wheatgrass	A. intermedium
AGSM	Western wheatgrass	A. smithii
AGTR	Pubescent wheatgrass	A. trichophorum
ARTR	Big sagebrush	Artemisia tridentata
ARTRW	Wyoming big sagebrush	A. t. wyomingensis
ATCA	Fourwing saltbush	Atriplex canescens
ATCO	Shadescale	A. confertifolia
ATCOR	Mat saltbush	A. corrugata
ATCU	Castle valley clover	A. cuneata
ATGA	Gardner saltbush	A. gardneri
BOGR	Blue grama	Bouteloua gracilis
CELA	Winterfat	Ceratoides lanata
CHNA	Rubber rabbitbrush	Chrysothamnus nauseosus
ELJU	Russian wildrye	Elymus junceus
ERUM	Sulfur eriogonum	Eriogonum umbellatum
HAHA	Siberian salt tree	Halimodendron halodendron
HEBO	Utah sweetvetch	Hedysarum boreale
HIJA	Galleta grass	Hilaria jamesii
KOPR	Prostrate summer cyress	Kochia prostrata
LILE	Lewis flax	Linum lewisii
MESA	Alfalfa	Medicago sativa
ORHY	Indian ricegrass	Oryzopsis hymenoides
PUTR	Bitterbrush	Purshia tridentata
SAVE	Greasewood	Sarcobatus vermiculatus
SPGR	Gooseberryleaf globemallow	Sphaeralcea grossulariaefolia
SPMU	Munro globemallow	S. munroana
STCO	Needle and Thread grass	Stipa comata
SUFR	Alkali seepweed	Sueda fruticosa

7.2 WHITE RIVER ECOSYSTEM METALS STUDY

7.2.1 Introduction

During 1982, White River Shale Oil Corporation funded an investigation in the White River, Utah to document the levels of metals related to oil shale development which might occur in the biota of the White River. The purpose of this program was to determine these levels as a baseline against which future data could be compared.

The selection of the test contaminants was dependent upon their relationship to the energy industry. Suspected compounds which may impact groundwater or surface water at the study site included: soluble salts; reduced sulphur species; soluble organics of highly variable composition; Mo; B; F; the trace metals, As, Cd, Se, Pb, Cr, Zn, Cu, Ni, Hg, Fe; and other undetermined contaminants (McWhorter 1980, Wildung and Zachara 1981). The potential impact of the industrial waste streams to surface and groundwater would depend upon the mass emissions of contaminants, various physical-chemical interactions between contaminants, the pollutant dynamics within receiving waters and the site-specific characteristics of terrestrial and aquatic environments. Based upon available information on waste stream characterization for the synthetic fuels industry, the following heavy metals were selected for this study: Cd, Cr, Cu, Pb, Ni and Zn.

Study Area: The White River, which drains approximately 10,250 km^2 flows through several distinct geomorphic regions. The drainage basin is comprised of an upper mountainous region from which a majority of the water originates and a lower, semi-arid basin through which the stream flows. This

lowland is frequented by intensive summer rainstorms which drastically alter the character of the river. As stated previously, the drainage basin has not been extensively developed, although deposits of oil shale from the Green River formation (Piceance Creek and Uinta Basins) are presently being mined. The dominant surfical deposits within the drainage basin are lacustrine sediments from Lake Uinta (Paleocene Epoch) which consist of marlstones dominated by dolomite and calcite. The water quality within the river changes markedly with distance downstream due to physio-chemical processes and ephemeral channel runoff. The White River also changes seasonally in both flow and quality with three distinct flow regimes having been observed: baseflow, lower basin runoff and upper basin runoff.

The relative concentrations of major anions/cations found in the White River, occur in the following order:

$$HCO_3^- > SO_4^{=} > Cl^- > CO_3^{=}$$

$$Ca^{2+} > Na^+ > Mg^{2+} > K^+ ,$$

This order reflects the geologic weathering and evaporation-crystallization processes taking place. In general, the highest concentrations of dissolved substances has occurred between August and March (baseflow), intermediate concentrations between April and May (lower basin) and the lowest concentrations during June and July (upper basin runoff). Data are shown in Table 7.2-1 for these runoff periods from October 1974 to September 1976. Long-term averages for the 1974 - 1980 period have indicated similar values. Suspended sediment (SS) concentrations in the river have

Table 7.2-1. The average concentrations for selected water quality parameters in the White River between October 1974 and September 1976[1].

	Baseflow (August-March)			Lower Basin Runoff (April-May)			Upper Basin Runoff (June-July)		
Parameter	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.
Alkalinity($mgCaCO_3/l$)	89	199	16	27	177	58	32	134	22
Dissolved Solids(mg/l)	81	526	51	25	588	44	29	293	74
Hardness(mg/l)	89	289	31	27	301	25	32	184	39
pH(units)	64	8.1	0.4	24	8.2	0.6	28	7.8	.6
Spec. Cond.(umhos/cm)	91	813	121	27	874	71	32	473	132
Temperature(mg/l)	38	10.0	8.8	30	6.3	5.1	32	15.5	3.9
Chloride(mg/l)	88	40.0	12.0	27	41.0	6.0	32	15.5	8.5
Sulfate(mg/l)	89	176	21	27	209	20	32	88	39
DOC(mg/l)	11	6.8	3.9	6	5.8	3.4	8	5.8	1.5
Fe(µg/l)	57	28	41	19	33	21	20	38	25
Ba(ug/l)	33	48	91	14	38	38	11	27	48
Al(ug/l)	55	17	16	19	30	25	19	30	19
Mn(ug/l)	56	4	8	18	9	7	20	38	25
Cu(ug/l)	51	6.0	22	19	41	82	11	4	4
Zn(ug/l)	45	21	34	19	12	16	11	4	5
Cd(ug/l)	46	<1	1	20	1	1	11	<1	.45
Cr(ug/l)	40	2	8	14	2	5	11	<1	<1
Pb(ug/l)	46	2	2	13	4	10	11	1	1
Ni(ug/l)	46	5	5	14	2	1	11	3	2

(1) Although values may change from year to year, the data presented in this table are representative of the different flow conditions (WRSOC 1977).

shown a direct relationship with streamflow. Sediment levels and flows fluctuate widely in response to local precipitation events (Figure 7.2-1). During baseflow, SS levels averaged 100-200 mg/l whereas during upper basin runoff the levels of SS were 100-5000 mg/l (depending upon stream flow). Furthermore, SS concentrations have been recorded as high as 37,600 mg/l in the White River near Watson, Utah in response to a storm event.

Metal levels were generally within the standards for the protection of aquatic life although at times the standards were exceeded or nearly exceeded for Cu, Pb, Hg, Zn and Ag (USEPA 1980). Previous studies (WRSOC 1974-1982) have indicated that the White River receives natural periodic heavy metals loads associated with storm events within its watersheds which frequently result in excessive levels of dissolved metal. For example, during March 1975, a storm event increased the flow of the White River from 500 to 1100 cfs, increased SS from 200 to 2500 mg/l and dissolved copper from 4 ug/l to 340 ug/l. This phenomena has been noted for other metals, particularly Zn, Pb and Cr (Medine, unpublished data).

7.2.2 Program Summary And Recommendations

The metals study conducted in the White River adjacent to Tracts Ua and Ub has provided site-specific data for future comparisons. More importantly, this study has allowed a brief look into the mechanisms regulating the heavy metal dynamics in the White River ecosystem. While this study has not provided the definitive description of metal dynamics in the White River, it has increased our understanding to the point that pending regulations may be quantitatively addressed. The conclusions to be drawn from this study include the following:

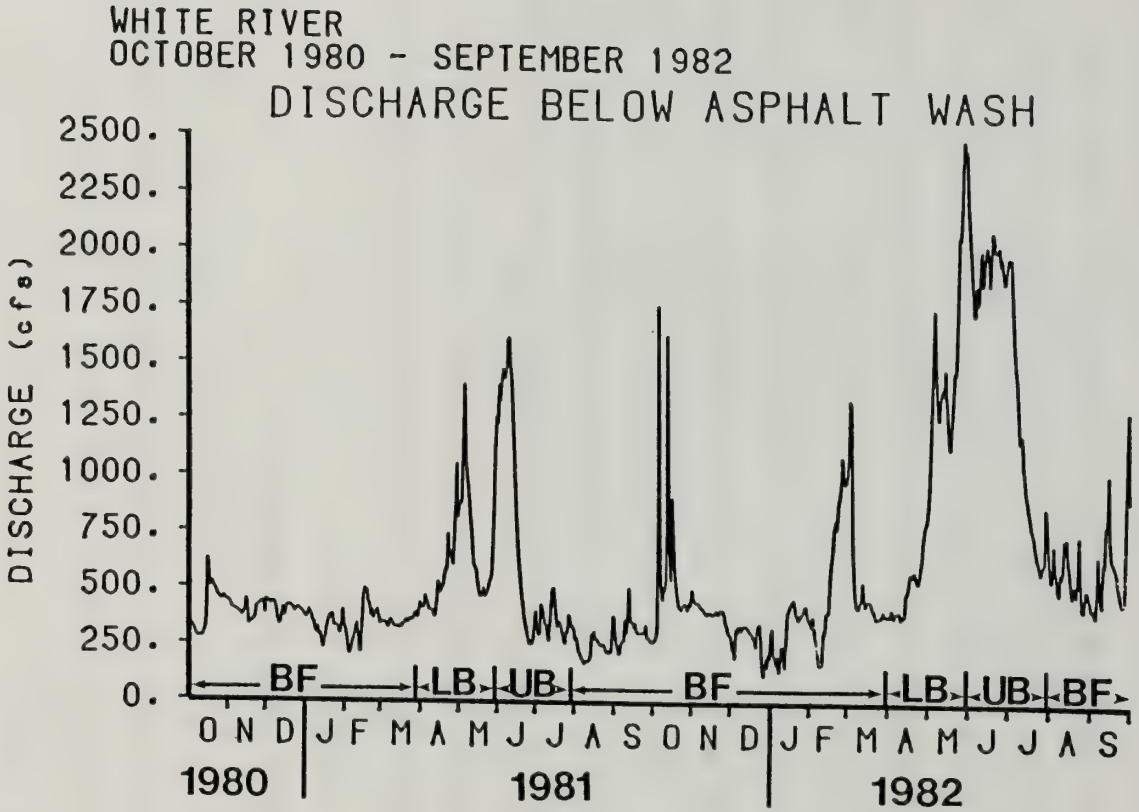

Figure 7.2-1. The discharge patterns for the White River between 1980 and 1982. BF = base flow; LF = lower basin runoff; UB = upper basin runoff.

- The metal concentrations in the ecosystem components of the White River are consistently higher than the background levels reported for uncontaminated systems.

- A major source of copper and most likely Zn into the White River are the dry washes and overland runoff.

- Spatial differences were found along transects and were correlated with the location of alluvial fans. An inspection of alluvial water quality indicated close agreement between well water quality (metal concentrations) and the elevated metal levels in the river organisms.

- Macroinvertebrates appeared to amplify the metal concentrations in the river water.

- Carbonate precipitates demonstrated the same pattern as the macroinvertebrates but appeared to provide a long-term average of river water quality.

- Although fish and sediment organics provide the same integrating capacity as the precipitates, they are extremely mobile and may not reflect site-specific conditions.

- The organisms in the White River appear to have adapted to the periodic high metal loads.

- Adsorption of metals by suspended sediments in the White River is a major mechanism of removal of the soluble form.

- It is believed that Chromium in the White River occurs dominantly as Cr^{+3} rather than Cr^{+6}. However, based upon concentrations in organisms adjacent to alluvial fans, alluvial water is most likely Cr VI.

- Nickel does not fit the classical adsorption pattern reported in the literature. It is believed that Ni is complexed or chelated in the river water and is prevented from interacting with solid phases.

7.2.3 Program Description

7.2.3.1 Study Objectives Specific objectives of this study were:

- Define the mechanisms of transport and transformation for selected metals in the White River (pathway identification).

- Determine the ultimate fate of selected metals in the White River ecosystem (structural distribution).

- Based upon study results, provide recommendations relative to the existing metals levels, metal loading locations, and future regulatory requirements.

7.2.3.2 Experimental Methods Three sites were selected along the middle course of the White River for the first set of samples taken on 4-25-82 (Figure 7.2-2). A more comprehensive collection was made on 10-8-82 encompassing six sites. The upstream site for both collections was in the White River at Cowboy Canyon and represented an area of the river above major outcrops of raw shale of the Green River Formation. The intermediate site, WRSOC monitoring transect WR03 (below Evacuation Creek), was selected because of its location relative to the only perennial tributary along this section of the White River (four miles below Cowboy Canyon) and the presence of raw shale outcrops within the river itself. The lower site sampled during the first collection was WRSOC monitoring transect WR18 at Southam Canyon, 10 miles downstream from the Evacuation Creek site. This site was adjacent to the Federal Lease Tracts Ua and Ub. The second collection included all of the above sites and the addition of a collection site immediately above Evacuation Creek, as well as sites above and below Asphalt Wash which was approximately 5.0 miles below the Southam Canyon site on the White River.

A. Field Methods At each site, a rocky substrate area was selected for sample collections. Periphyton was scraped or picked from the rock substrates, placed in plastic bags, frozen and returned to the laboratory. In a similar manner, rocks which contained a white precipitate were scraped in the field, placed in a plastic bag, frozen and returned to the laboratory.

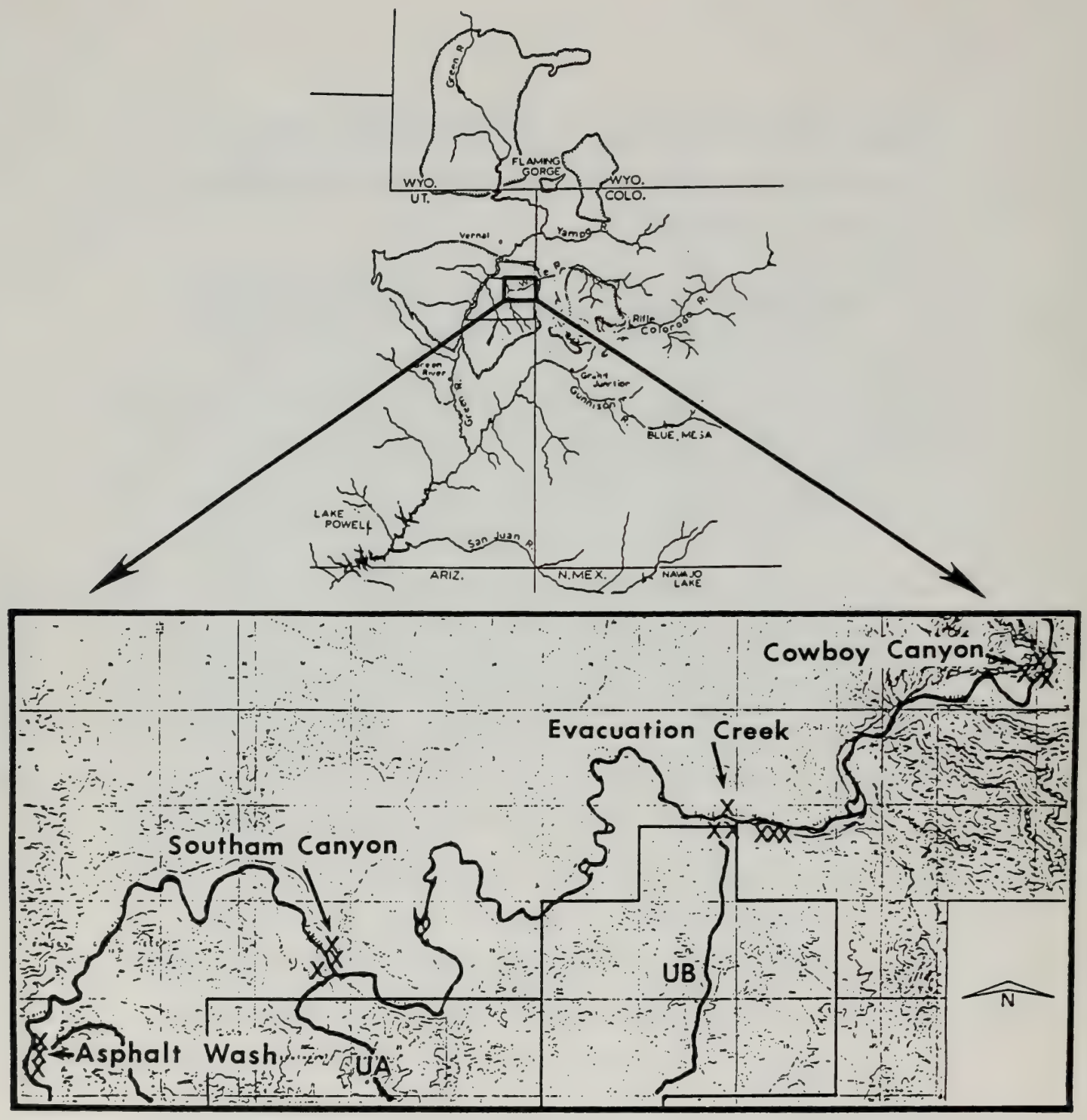

Figure 7.2-2. The location of the White River and the Federal Lease Tracts Ua-Ub. Sample sites are noted by "x".

Coarse detritus was collected concurrently with the macroinvertebrate samples. Substrate sediment samples were collected from the stream bottom and returned to the laboratory for drying and screening (<0.25mm). Fish were collected by seining at each site, frozen and returned to the laboratory for processing.

B. Laboratory Methods Periphyton, precipitates, sediments, macroinvertebrates, detritus and fish were separated, air dried, dissected if necessary and homogenized. The solid samples were then freeze-dried prior to preparation for digestion. Dried samples were weighed to the nearest 0.01 mg prior to digestion with the total weight for most samples between 0.500 and 1,000 g. Samples which were less than 0.500 g were digested in a micro-digestion apparatus which used smaller digestion tubes (approximately 10 ml) and proportionally reduced reagent volumes.

All glassware was thoroughly washed and soaked overnight in 1:1 HCl and rinsed with reagent grade water (Millipore Milli-Q System). Hot 1:1 nitric acid was added to each piece for an additional 24-hour soaking. Final preparation included three rinses with reagent grade water and one additional soak with 1:4 HNO_3 (ultra-pure) and three final rinses with reagent grade water. Results indicated very little contamination from reagents and processing of the samples. The digestion procedure involved a nitric acid and hydrogen peroxide digestion of the samples in a Tecam block digestor programmed for at least 8 hours of digestion at 150°C. Dried samples were placed in 75 ml digestion tubes, followed by 5.0 ml of HNO_3. Digestion was carried out for several hours after which 2.0 ml of H_2O_2 was added to each tube. Blanks were carried through the entire process for subtraction of

metal mass in reagents and water used in the process. Solid samples from the National Bureau of Standards and aqueous metal samples from the EPA were used to evaluate recovery (95-100%) and to establish appropriate instrumental parameters. After digestion, samples were filtered (if necessary) and brought up to a defined volume (75 ml-macro; 10 ml-micro).

The analysis of sample extracts was carried out using an Instrumentation Laboratory Model IL-551 Atomic Absorption Spectrophotometer equipped with a Model IL-555 graphite furnace and a Model IL-254 Fastac Autosampler. Relative standard deviations (n=3) for all standards were kept below 2.0% and were generally 1.0% or less. Samples were analyzed in the linear range or diluted to respond to the linear range of the instrument. A minimum of five standards were used to generate standard curves. Additional analyses were conducted on the precipitates for Al, Fe, Ba, Mn, Ca and Mg by an Instrumentation Laboratory Model IL-200 Inductively Coupled Argon Plasma Spectrometer.

7.2.4 Program Results and Analysis

As noted in the previous section, two separate collections for metals were made at selected sites along the White River during 1982. These two time periods represented different hydrological conditions within the river system. The first sample period (4-25-82) represented a period of time where flow conditions were low and TDS levels high (Table 7.2-2). The biological community reflected these conditions with high biomass levels. However, the second set of samples was taken after spring runoff in an unusually wet summer with frequent storm events (Figure 7.2-1). Flow was substantially higher and TDS levels lower. The biomass levels at the same sites were also

Table 7.2-2. A comparison of physical, chemical and biological structural parameters in the White River at two representative riffle transects during the two sample periods.

Parameter	Location	Date	N	Mean±S.E.	Min	Max
Fine Detritus (%)	WR03[1]	4/82	6	1.02 ± .06		
		10/82	5	.57 ± .10		
	WR18[2]	4/82	5	1.06 ± .08		
		10/82	5	.76 ± .20		
Coarse Detritus (g/m^2)	WR03	4/82	6	51.8 ± 17.8		
		10/82	5	10.5 ± 3.1		
	WR18	4/82	9	97.4 ± 46.1		
		10/82	5	17.6 ± 5.4		
Algae (mg Chl a/m^2)	WR03	4/82	5	61.8 ± 21.6		
		10/82	3	36.8 ± 6.9		
	WR18	4/82	5	43.0 ± 14.5		
		10/82	5	24.4 ± 15.3		
Macroinvertebrates($\#'s/m^2$)	WR03	4/82	6	135 ± 71		
		10/82	5	80 ± 80		
	WR18	4/82	8	71 ± 25		
		10/82	5	120 ± 28		
Macroinvertebrates(mg/m^2)	WR03	4/82	6	50 ± 31		
		10/82	5	4 ± 4		
	WR18	4/82	8	72 ± 33		
		10/82	5	34 ± 15		
Organic Drift (g/hr)	WR18	4/82	3	73.7 ± 13.7		
		10/82	2	159.8 ± 25.9		
Flow (cfs)	WR27[3]	4/81 to 4/82	28	477 ± 61	176	1489
		5/82 to 10/82	14	1183 ± 171	454	2050
TDS (mg/l)	WR27	4/81 to 4/82	19	465 ± 18	336	562
		5/82 to 10/82	22	303 ± 22	159	467
Conductivity (umhos/cm)	WR27	4/81 to 4/82	26	736 ± 31	578	898
		5/82 to 10/82	21	499 ± 234	234	659
pH (units)	WR27	4/81 to 4/82	30	8.19 ± .05	7.40	8.70
		5/82 to 10/82	22	7.95 ± .06	7.38	8.68

(1) WR03 = Evacuation Creek Site
(2) WR18 = Southam Canyon Site
(3) WR27 = Asphalt Wash Site

reduced substantially.

7.2.4.1 Structural Distribution A comparison of the metal concentrations in the various components of the White River ecosystem for the two dates can be seen in Table 7.2-3. These values represent the mean concentrations for a sample date, regardless of site location. In general, Cd, Cr and Ni were reduced in concentration for all ecosystem components between the two samples dates, whereas Zn, Cu and Pb decreased in only one-half of the compartments.

During the 4-25-82 sample period, the following sequence was observed for the metal concentrations in the ecosystem (highest to lowest):

macroinvertebrates>coarse detritus>fine detritus>algae>fish>precipitates

This sequence changed during the 10-8-82 sample period with the following order being noted:

coarse detritus>algae>macroinvertebrates>precipitates>fish

Although these are general sequences and tend to vary from metal to metal, the organic phases (detritus, algae or macroinvertebrates) were always higher in concentration when compared to fish or $CaCO_3$ precipitates.

A spatial comparison of the metal levels by trophic groups (Table 7.2-4; Figures 7.2-3 and 7.2-4) indicated that the abiotic compartments (carbonate precipitate and the fine detritus sediment fraction) increased with distance downstream but did not demonstrate wide variability. A similar pattern was

Table 7.2-3. A summary of metals data collected in the White River by date during the special study.

Compartment	Date	No.	Metal Concentrations ($\bar{x} \pm$ S.E.; ug/g D.W.) Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Water (ug/l)			.136 ± .074	3.14 ± .95	2.65 ± .46	.64 ± .26	3.47 ± .79	14.0 ± 4.9
	4-25-82	(6)	.58 ± .16	38.5 ± 7.4	16.9 ± 1.5	10.3 ± 1.57	19.9 ± 2.5	23.9 ± 2.9
Precipitate ($CaCO_3$)	10-8-82	(12)	.43 ± .03	31.7 ± 3.7	12.4 ± .41	12.7 ± .61	8.28 ± 1.06	30.67 ± 2.71
Fine Detritus-Sediments	4-25-82	(3)	1.05 ± .12	67.5 ± 7.0	19.2 ± .58	35.6 ± 2.27	24.8 ± .96	78.1 ± 3.2
Coarse Detritus	4-25-82	(2)	2.48 ± .67	29.1 ± 15.5	122.1 ± 102.0	17.6 ± 12.7	24.7 ± 19.4	206.0 ± 37.0
	10-8-82	(21)	.80 ± .04	14.3 ± .88	51.4 ± 3.9	17.9 ± .5	8.81 ± .47	70.0 ± 3.1
Algae	4-25-82	(4)	1.29 ± .12	58.6 ± 8.0	14.6 ± 4.9	22.4 ± 1.8	23.9 ± 4.3	83.2 ± 24.1
	10-8-82	(14)	.47 ± .06	43.4 ± 2.8	27.2 ± 4.7	45.5 ± 11.5	14.4 ± 1.3	50.0 ± 4.3
Macroinvertebrates								
Predators	4-25-82	(2)	14.3 ± 8.6	85.4 ± 54.0	56.4 ± 17.0	28.8 ± 16.0	37.8 ± 23.0	219.0 ± 20.0
	10-8-82	(3)	2.33 ± 1.04	12.9 ± 7.63	80.7 ± 52.1	9.99 ± 4.78	3.42 ± 2.26	623.0 ± 447.0
Omnivores	4-25-82	(1)	1.61	60.5	43.4	8.8	35.1	226.0
	10-8-82	(14)	2.11 ± .64	7.44 ± 1.18	85.1 ± 29.9	10.9 ± 2.49	4.25 ± .94	437.0 ± 203.0
Total Macroinvertebrates	4-25-82	(6)	12.9 ± 6.5	72.5 ± 23.4	92.1 ± 25.5	20.4 ± 6.8	47.5 ± 14.8	275.0 ± 31.3
	10-8-82	(17)	2.15 ± .55	7.85 ± 1.36	84.3 ± 25.7	10.71 ± 2.16	4.11 ± .85	469.0 ± 180.0
Fish								
Flannelmouth	4-25-82	(2)	1.67 ± .05	13.89 ± 6.8	12.4 ± .09	3.63 ± .15	6.01 ± 2.5	118.1 ± 13.4
	10-8-82	(4)	.26 ± .03	2.02 ± .44	40.1 ± 7.1	1.11 ± .18	.79 ± .14	74.0 ± 3.1
Chubs	4-25-82	(5)	2.35 ± .94	8.08 ± 3.3	26.6 ± 15.2	2.35 ± .71	3.93 ± .89	265.0 ± 43.0
	10-8-82	(3)	.21 ± .05	2.23 ± .96	32.2 ± 1.9	1.16 ± .21	.25 ± .06	126.0 ± 12.8
Blueheads	4-25-82	(2)	1.07 ± .22	5.17 ± .80	16.4 ± 1.3	2.52 ± .01	2.52 ± .24	73.5 ± 1.4
	1-8-82	(2)	.14 ± .02	7.06 ± 1.8	33.2 ± 7.8	2.34 ± .48	1.35 ± .55	81.3 ± 7.6
Speckled Dace	4-25-82	(1)	0.93	1.26	10.2	0.79	1.96	218.0
	10-8-82	(4)	.36 ± .04	1.36 ± .42	20.1 ± 3.4	.79 ± .12	.34 ± .13	135.0 ± 14.0
Total Fish	4-25-82	(11)	1.94 ± .45	7.79 ± 2.20	18.6 ± 6.9	2.44 ± .38	4.98 ± 1.33	193.0 ± 31.0
	10-8-82	(14)	.26 ± .03	2.65 ± .59	30.4 ± 3.1	1.45 ± .28	.68 ± .14	110.5 ± 9.7

Table 7.2-4. The temporal and spatial concentration of metals in various trophic categories of the White River.

COWBOY CANYON

		Metal Concentration (ug/g dry weight; $\bar{x} \pm$ S.E.)					
	Date	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Precipitate	4-25-82	0.17 ± .07	40.9 ± 11.9	12.9 ± 1.03	5.71 ± 0.15	24.6 ± 3.5	26.2 ± 2.5
	10-8-82	0.42	33.8	11.4	6.16	11.5	27.9
Algae	4-25-82	0.32	9.5	8.1	10.8	4.9	29.0
	10-8-82	1.09	40.6	19.7	10.4	27.9	34.6
Fine Detritus	4-25-82	0.82	62.2	19.8	36.2	25.8	77.2
	10-8-82	--	--	--	--	--	--
Coarse Detritus	4-25-82	--	--	--	--	--	--
	10-8-82	0.56	11.8	26.2	6.58	14.4	44.5
Macroinvertebrates(all species)	4-25-82	50.7	14.8	49.3	1.38	49.0	172.0
	10-8-82	0.59	1.29	0.94	0.21	0.79	19.3
Fish (all species)	4-25-82	1.51 ± .20	4.35 ± 0.5	9.9 ± .7	1.99 ± 0.23	5.11 ± 1.35	154.0 ± 17.5
	10-8-82	0.23 ± .01	1.52 ± 0.2	34.6 ± 1.6	0.61 ± 0.9	0.98 ± .08	99.6 ± 10.6

BELOW EVACUATION CREEK

		Metal Concentration (ug/g dry weight; $\bar{x} \pm$ S.E.)					
	Date	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Precipitate	4-25-82	0.99 ± 0.1	43.5 ± 10.4	17.8 ± 0.3	11.9 ± 1.0	20.2 ± 0.4	29.2 ± 0.4
	10-8-82	0.34	10.4	5.32	5.36	8.20	28.7
Algae	4-25-82	1.05	46.2	17.4	27.0	17.9	54.1
	10-8-82	0.34 ± .11	53.9 ± 3.8	30.2 ± 10.7	18.5 ± 1.6	43.2 ± 12.8	66.9 ± 6.9
Fine Detritus	4-25-82	1.11	58.9	18.0	31.4	22.7	73.1
	10-8-82	--	--	--	--	--	--
Coarse Detritus	4-25-82	1.80	44.6	203.0	30.2	44.2	243.0
	10-8-82	0.75 ± .10	21.1 ± 6.7	57.3 ± 11.5	20.2 ± 4.0	7.58 ± .47	66.7 ± 5.5
Macroinvertebrates(all species)	4-25-82	39.1	117.0	79.2	19.9	103.0	254.0
	10-8-82	0.76 ± .08	4.58 ± 1.12	14.9 ± 1.90	2.08 ± .99	2.01 ± 1.06	208.0 ± 17.0
Fish (all species)	4-25-82	1.54 ± .15	5.17 ± 0.44	13.8 ± 1.29	1.75 ± .21	3.13 ± .62	186.0 ± 33.0
	10-8-82	0.21 ± 0.6	5.02 ± 2.70	30.3 ± 6.4	1.89 ± .60	0.94 ± .51	110.0 ± 29.0

SOUTHAM CANYON

		Metal Concentration (ug/g dry weight; $\bar{x} \pm$ S.E.)					
	Date	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Precipitate	4-25-82	0.58 ± .01	31.0 ± .01	20.1 ± 1.5	13.5 ± 0.2	18.7 ± .01	25.7 ± 4.9
	10-8-82	0.44 ± .06	25.2 ± 1.5	13.6 ± 1.5	7.27 ± .54	12.0 ± .15	23.0 ± 1.5
Algae	4-25-82	1.42	49.9	12.6	21.0	17.4	50.8
	10-8-82	.72 ± .01	42.9 ± 13.4	31.9 ± 4.6	15.4 ± 8.7	52.8 ± 23.4	54.3 ± .0
Fine Detritus	4-25-82	1.22	81.6	19.7	39.2	25.8	84.2
	10-8-82	--	--	--	--	--	--
Coarse Detritus	4-25-82	3.15	13.5	41.1	4.94	5.27	169.0
	10-8-82	.79 ± .04	11.3 ± .60	53.2 ± 3.5	8.95 ± .68	17.1 ± .3	62.7 ± 5.8
Macroinvertebrates(all species)	4-25-82	9.06 ± 2.50	64.6	206.0	23.5	55.7	335.0
	10-8-82	0.52	12.5	198.0	6.73	14.1	309.0
Fish (all species)	4-25-82	3.07 ± .70	16.8 ± 2.75	37.9 ± 14.4	3.87 ± .32	6.59 ± 1.0	267.0 ± 52.0
	10-8-82	0.27 ± .04	2.12 ± .59	28.3 ± 1.8	0.50 ± .20	1.71 ± .70	123.0 ± 17.0

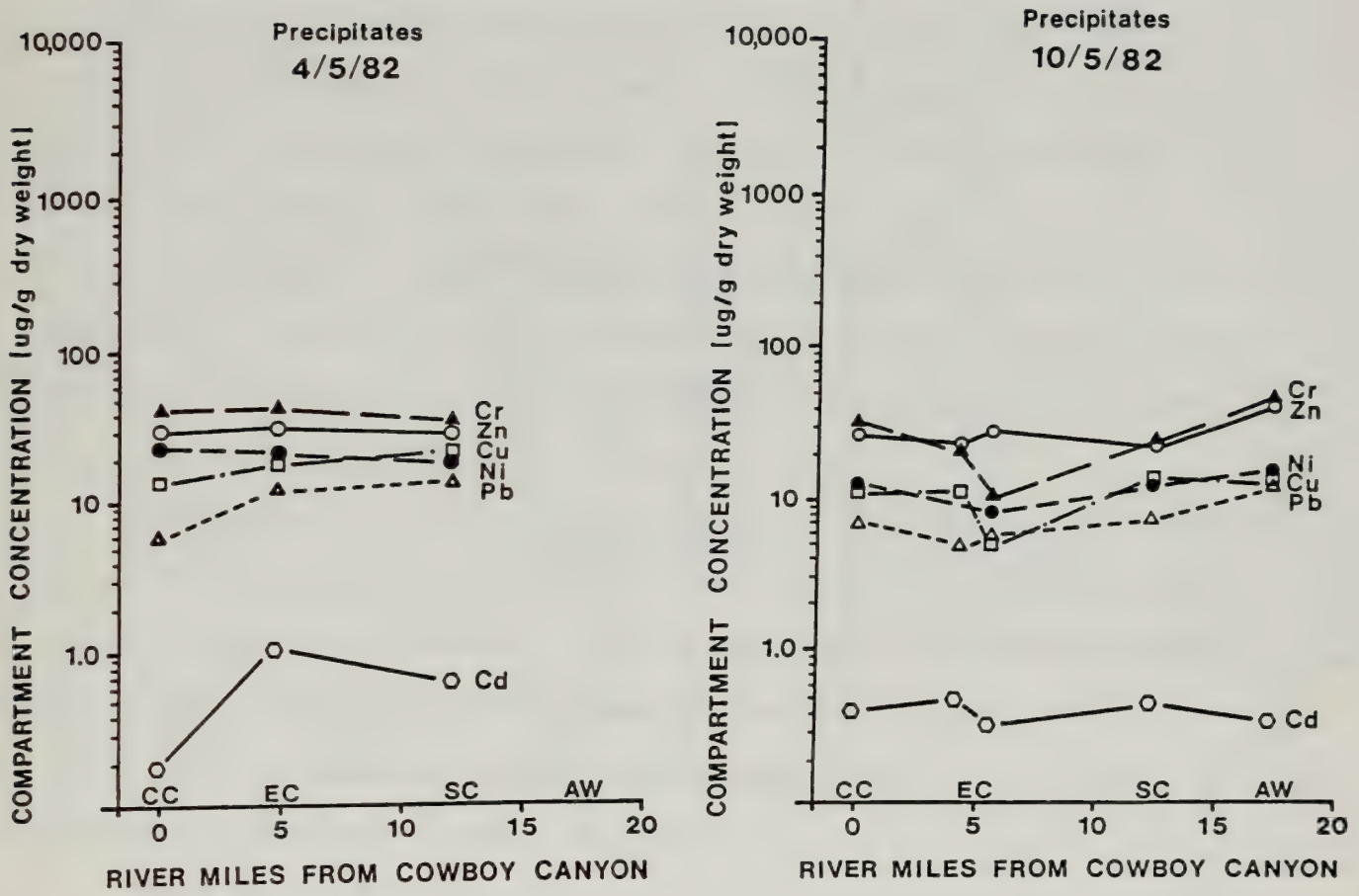

Figure 7.2-3. The distribution of metal concentrations in precipitates collected at different sites from the White River on 4/5/82 and 10/5/82.

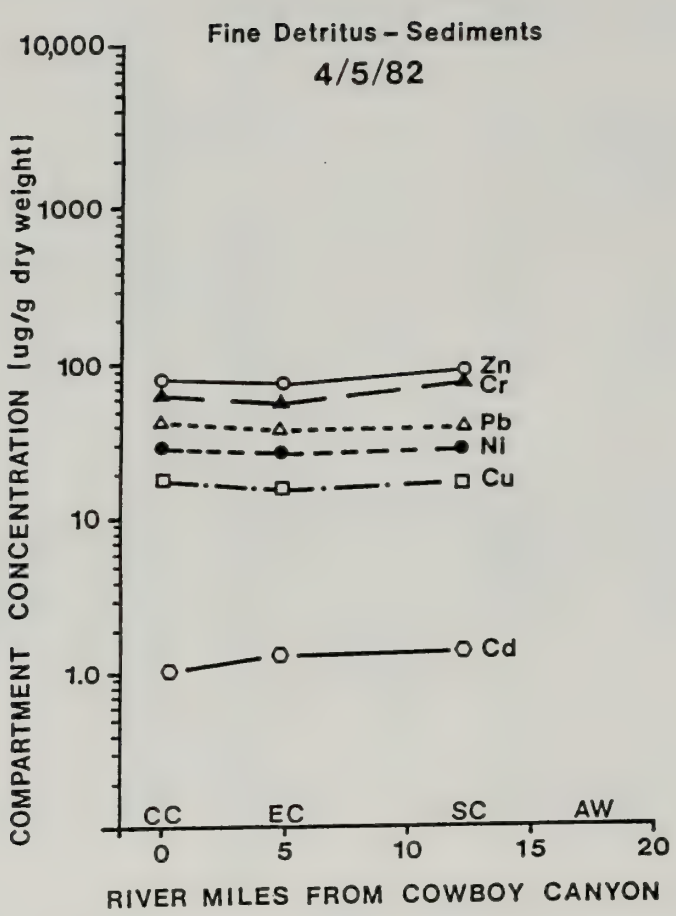

Figure 7.2-4. The distribution of metal concentrations in fine detritus from sediments collected at different sites from the White River on 4/5/82.

found for the fish. A comparison between dates for the precipitates and fish indicated that their respective metal sequences (highest to lowest concentration) were the same for both sample dates (Figures 7.2-3 and 7.2-5). It is interesting to note that the Cr, Ni, Cu and Cd metal concentrations in the precipitated carbonates were reduced in the river just below Evacuation Creek (site WR03) during the second sample period. A detailed analysis was undertaken to better define the composition of these precipitated materials. A preliminary analysis can be seen in Table 7.2-5 for four of the sites sampled on 10-5-82. A comparison of calcium carbonate concentrations in the precipitates from above and below Evacuation Creek indicated that the calcium component of the precipitate increased downstream from the Evacuation Creek site (14.2 to 44.3 mg Ca^{++}/gm precipitate).

In a similar manner, the concentration of metals within the fish trophic structure was further refined to include species with different food habits as well as metal concentrations in various fish organs. A comparison between the two sample dates for the body metal loads of the fish indicated species-specific changes. During the first sample period the following sequence was observed from highest to lowest:

roundtail chub>flannelmouth sucker>bluehead sucker>speckled dace

However, during the second sample period the following sequence was observed with a translocation of bluehead suckers and roundtail chubs:

bluehead sucker>flannelmouth sucker>roundtail chub>speckled dace

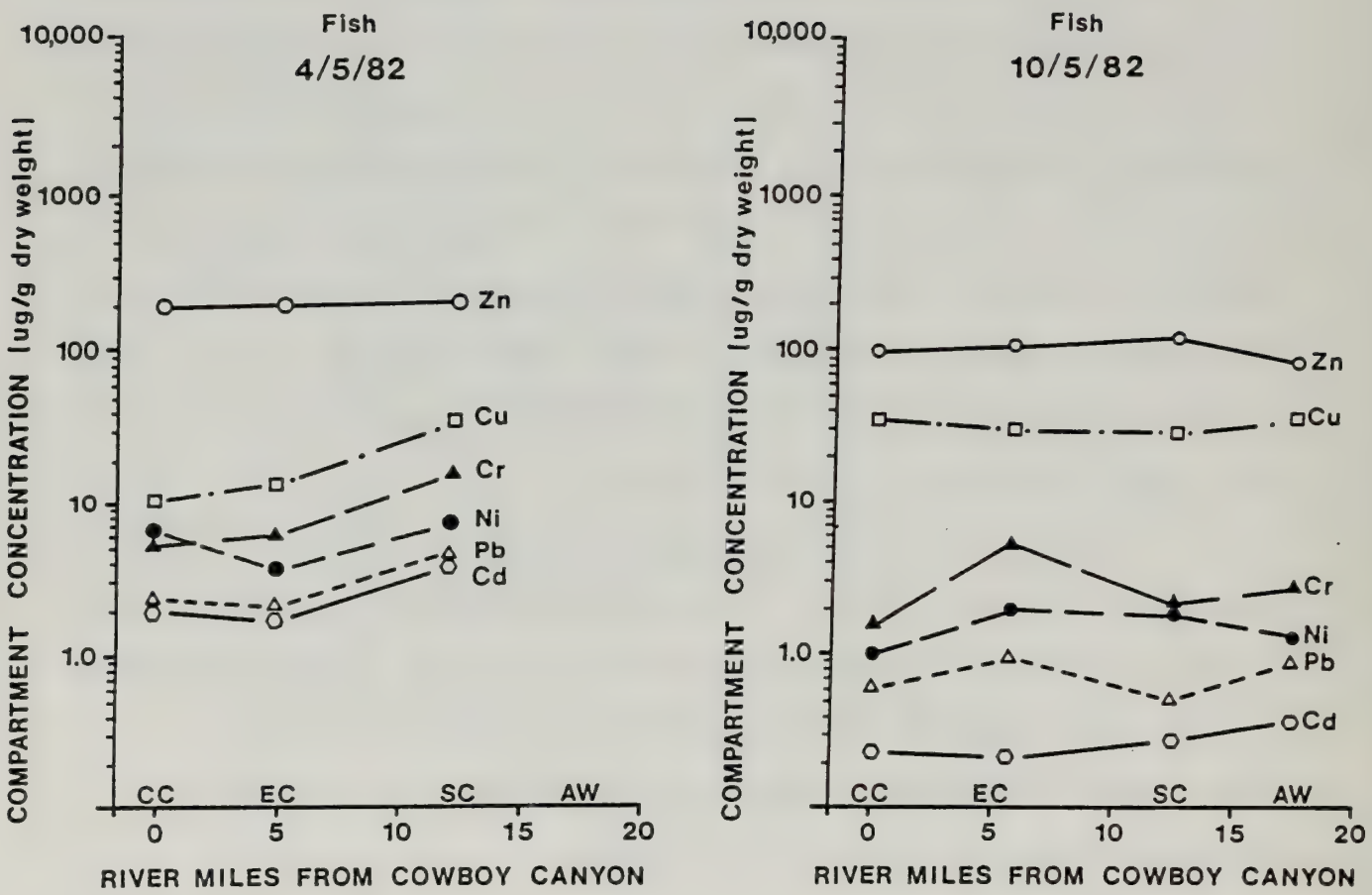

Figure 7.2-5. The distribution of metal concentrations in fish collected in the White River on 4/5/82 and 10/5/82.

Table 7.2-5. The ICP analysis of the elemental components of the precipitates collected from the White River on 10-8-82.

White River Location	Concentration (mg/g)					
	Al	Fe	Ba	Mn	Ca	Mg
Cowboy Canyon	9.5	9.0	0.33	0.42	14.2	6.8
Above Evacuation Creek	7.2	7.0	0.23	0.36	14.3	6.9
Southam Canyon (WR18)	8.3	9.8	0.33	0.49	44.3	15.5
Asphalt Wash (WR27)	12.8	15.3	0.48	0.44	26.4	12.2

The distribution of cadmium in fish organs can be seen for the study locations on 10-8-82 in Table 7.2-6. The metal concentration of various organs did display changes by sample site. For example, the concentration in skin increased steadily with distance downstream, whereas the bone, muscle and liver had a marked depression at the Evacuation Creek site. The cadmium concentration in the gastrointestinal tract corresponded well with the cadmium levels of the stomach contents for the same fish. A comparison of the mean cadmium concentrations in the organs (including all sites) indicated the following sequence of highest to lowest concentrations:

liver>kidney>gastrointestinal>fat>bone>skin>ovaries>muscle

The liver contained the highest concentrations (7.43 ug Cd/g d.w. $\pm$ 3.32) while the muscle had the lowest (.067 ug Cd/g d.w. $\pm$ .014). It appeared that analyses on whole fish for total body load for cadmium was an adequate measure of the weighted mean for all tissues. The total body load also represented a lower degree of variability similar to the muscle over distance downstream and time.

Contrary to the concentrations in the precipitates and fish, the macroinvertebrates and algae domonstrated a high degree of variability with distance downstream. For both sample dates, the concentration of all metals in the algae increased between Cowboy Canyon and the sample site below Evacuation Creek (WR03). A more detailed investigation on 10-5-82 refined the spatial distribution of the metals. These data (Figure 7.2-6) indicate

Table 7.2-6. The cadmium concentration of fish organs at selected locations in the White River, Utah. Values represent mean (±S.E.) concentrations in bluehead suckers and roundtail chubs collected on 10-8-82.

Location in The White River	Cadmium Concentration (mean±S.E.) in Organs (ug Cd/g dry weight)								
	Skin	Gastro-intestinal	Bone	Muscle	Fat	Liver	Kidney	Ovaries	Stomach Contents
Cowboy Canyon	.121±.06	.718±.268	.212±.133	.094±.021	.226	11.43	--	--	.651±.32
Evacuation Creek	.183	.805	.053	.034	--	.254	--	--	.473
Southam Canyon	.259±.116	1.43±.17	.104±.018	.081±.041	.480	10.51±10.08	--	--	3.47±2.79
Asphalt Wash	.739±.343	.857±.014	.88±.21	.043±.014	1.02±.59	5.95±4.35	5.70	0.205	.67±.58
Mean(±S.E.)	.343±.141	.973±.138	.349±.152	.067±.014	.689±.315	7.43±3.32	5.70	0.205	1.44±.81

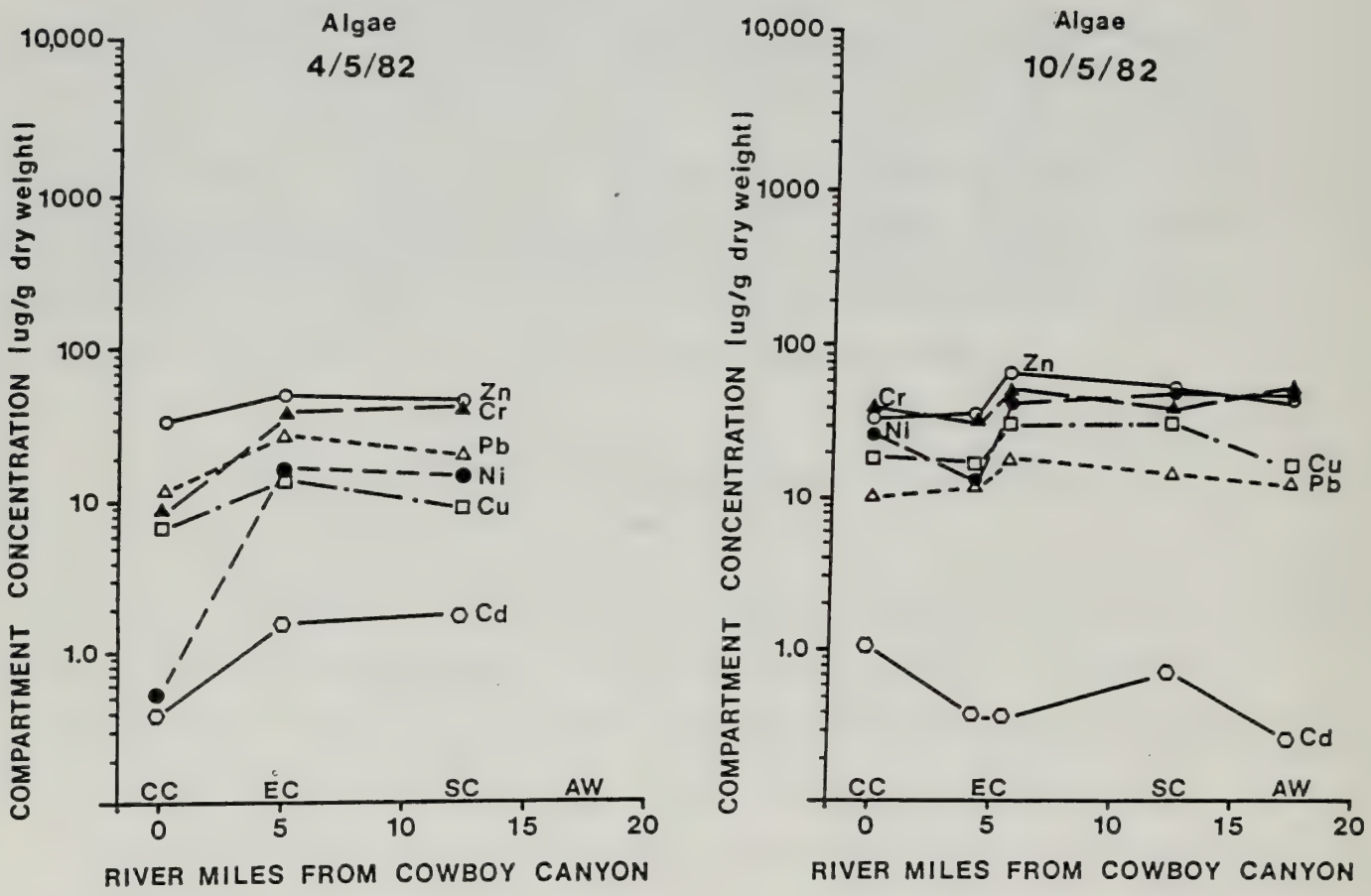

Figure 7.2-6. The distribution of metal concentrations in algae collected in the White River on 4/5/82 and 10/5/82.

that the metal content of the algae increased just downstream from the confluence of the White River with Evacuation Creek. A similar pattern was seen for coarse detritus during the second sample period in October (Figure 7.2-7).

Although the general pattern of the metal content in the macroinvertebrates was an amplification of trends observed in the other ecosystem compartments, metal levels in the macroinvertebrates sampled during the second collection decreased immediately below Evacuation Creek (Figure 7.2-8). However, below Evacuation Creek the metal concentrations in macroinvertebrates were found to be still higher than any trophic group or compartment sampled at that location.

7.2.4.2 Ecosystem Dynamics and Pathway Identification The concentrations of trace elements in most aquatic environments are usually very low (Riley and Chester 1971) although, as noted above, higher concentrations can occur in river and lake systems associated with natural and anthropogenic metal sources. These metal sources can substantially increase the heavy metal concentrations above levels normally encountered by the aquatic biota. Increases in both the essential (copper, zinc, iron and others) and nonessential (lead, cadmium, mercury, arsenic and others) metals may play an important role in regulating both the structure (Zanella 1982) and function (Medine and Porcella 1980) of the aquatic ecosystem. Furthermore, investigations of heavy metal pollution of the environment have shown that, depending on the trophic compartment studied, the results can lead to different interpretations regarding the toxicity of the ambient metal concentrations. It has been suggested that, where possible, any

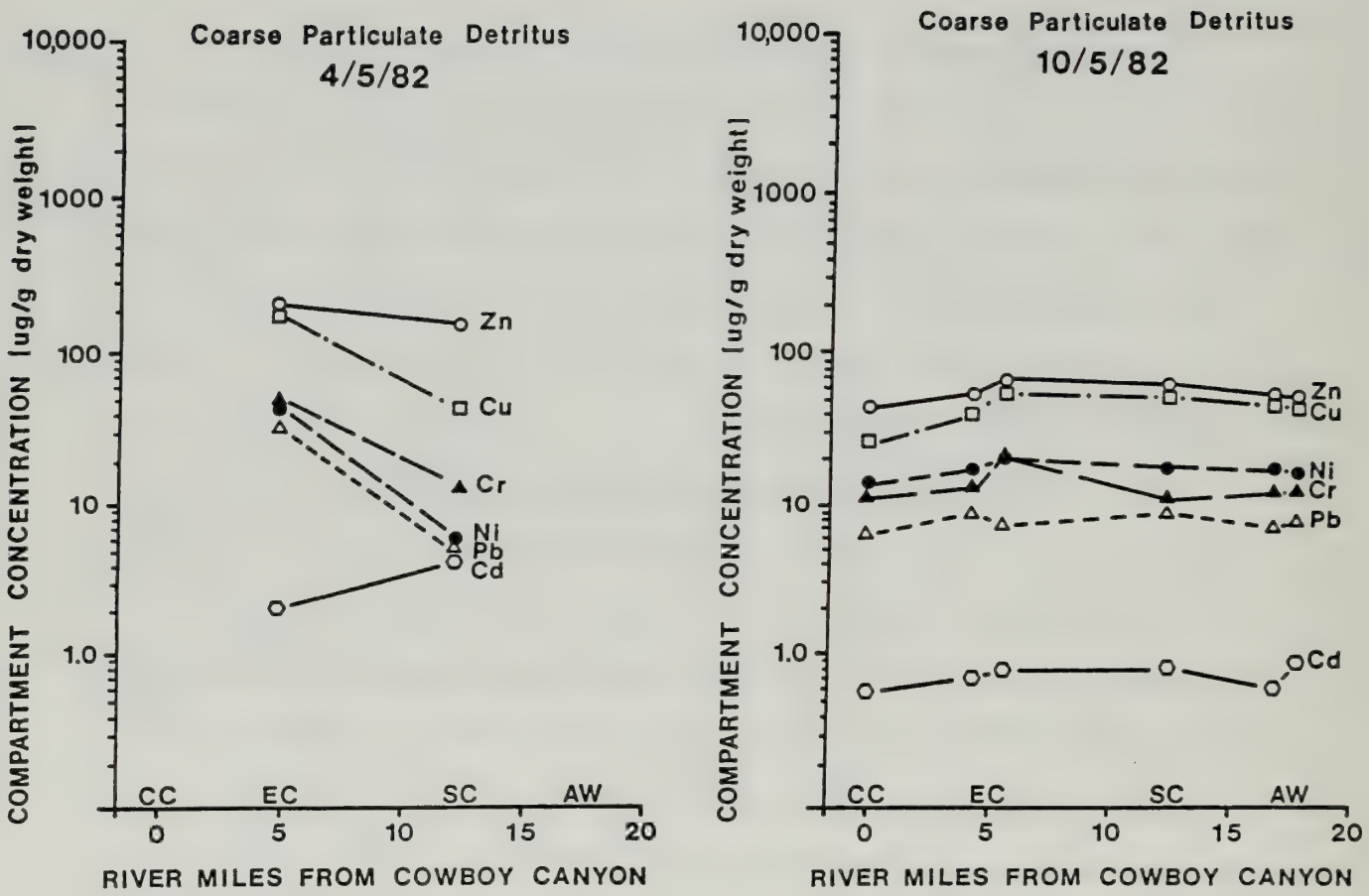

Figure 7.2-7. The distribution of metal concentrations in coarse detritus collected in the White River on 4/5/82 and 10/5/82.

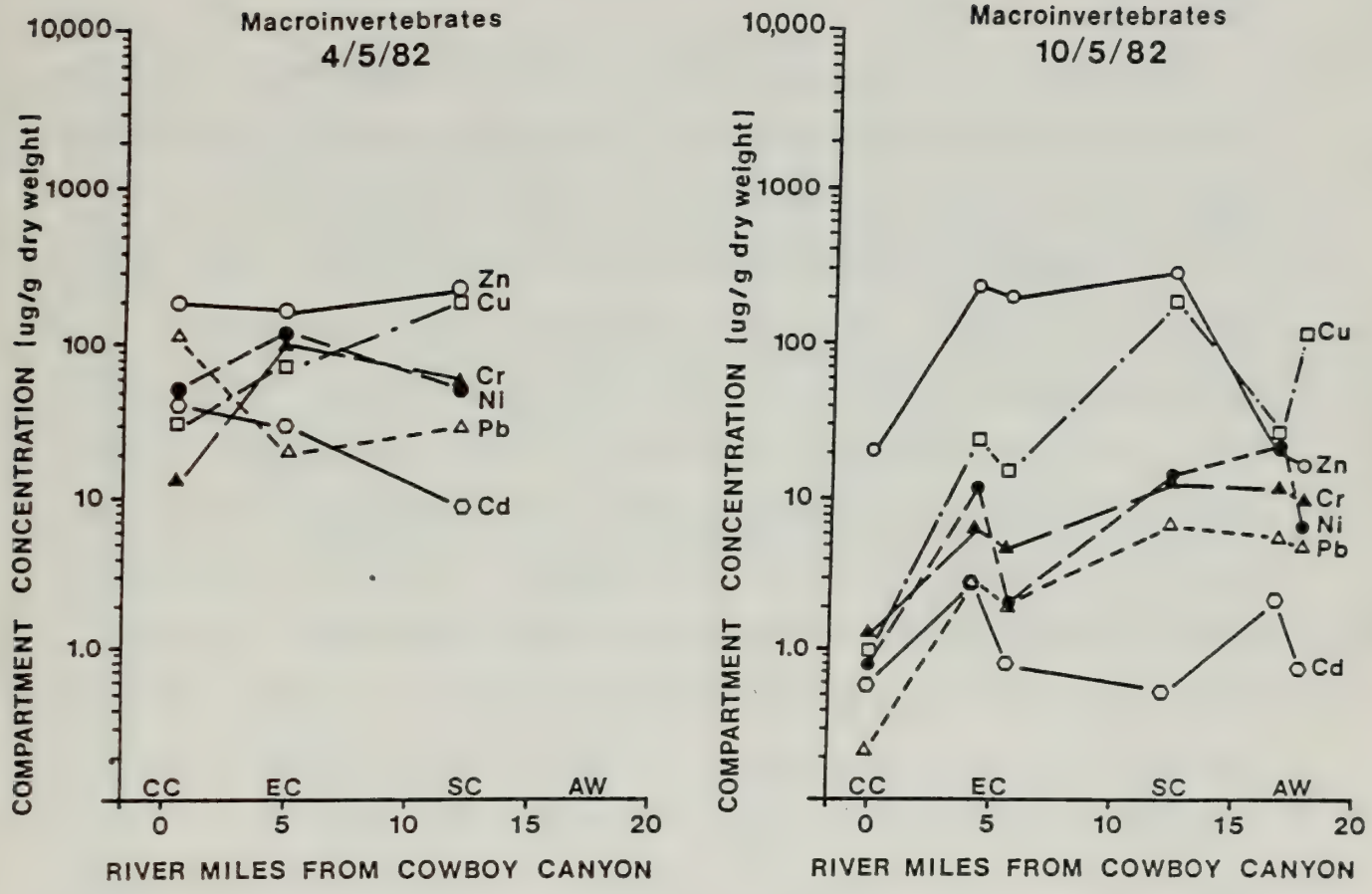

Figure 7.2-8. The distribution of metal concentrations in macroinvertebrates collected in the White River on 4/5/82 and 10/5/82.

investigation of the impacts of heavy metal enrichment on the aquatic environment simultaneously determine the metal concentrations in as many trophic levels as possible (Forstner and Whittman 1981) and determine the functional responses of the ecosystem to elevated metal concentrations (Medine et al. 1980).

As noted in the Program Description, one of the objectives of this study was to define the transport mechanisms, transformation processes and ultimate fate of metals in the White River (pathway identification).

A. Transport Mechanisms For the undisturbed White River study reach, the source locations for mass metal loadings may include; atmospheric deposition, upstream inflow, tributary or overland inflow and accrual (WRSOC 1982). Point sources may also be included for some river segments. Within the stream reach studied on the White River, the latter three processes appear to be important metal sources. Because of the annual fluctuation in flow, the water quality of the White River as an upstream source has been defined for the three major hydrologic periods (Table 7.2-1) and as annual averages (Table 7.2-7). In addition, another potential source of metals to the White River can be seen in Table 7.2-7, which represents the average water quality from the perennial Evacuation Creek and for two major ephemeral streams Southam Canyon and Asphalt Wash. The information collected in this study indicated that alluvial accrual may also represent a major source of metals to the White River system (Figure 7.2-9). Alluvial water quality from wells in each of the above major drainages has indicated high metal content in alluvial water (Table 7.2-8). It is believed that this water was entering the stream because of significantly higher metal levels in macroinvertebrates

Table 7.2-7. The concentration of selected water quality parameters for several surface water sources to the study section of the White River. (Source WRSOC 1977)

	Surface Waters											
	White River (09306500)			Evacuation Creek[1] (09306430)			Southam Canyon[2] (09306610)			Asphalt Wash[2] (09306625)		
	mean±S.E.	max	min	mean±S.E.	max	min	mean±S.E.	max	min	mean±S.E.	max	min
Total Alkalinity($mgCaCO_3/l$)	181±4	250	107	371±11.14	450	98	164±15	189	119	139±32	189	39
Dissoloved Solids(mg/l)	491±16	913	213	3290±110	4710	793	579±150	990	260	642±240	1330	305
Total Hardness(mg/l)	270±6	440	140	1040±31	1200	250	147±34	220	84	144±35	230	68
pH(units)	8.14±.04	8.8	7.2	7.93±.04	9.0	7.3	8.0±.03	8.1	7.9	7.7±.4	8.0	7.4
Conductance(umhos/cm)	751±21	1290	290	4100±113	5800	1200	789±250	1480	330	1092±350	1920	418
Sulfide(mg/l)	.148±.06	1.9	0.0	.187±.07	2.0	0.0	0			.10±.08	0.2	0
Dissolved Organic Carbon(mg/l)	5.57±0.7	9.9	2.9	14.4±2.2	35	6.2	8.50±2.5	12.0	5.0	13.0±.05	13.0	12.0
Orthophosphate(mgP/l)	.017±.03	.170	0.0	.0104±.001	.04	0.0	.083±.03	.09	.08	.08±.02	0.11	0.04
Total Phosphorus(mgP/l)	.165±.03	1.10	0.0	.0168±.003	.11	.001	7.90±2.4	14.0	1.8	23.0±12.0	40.0	5.90
Ammonia(mgN/l)	.0298±.005	.190	0.0	.0316±.004	.12	.005	.070±.010	.07	.06	.045±.03	.09	0.0
Nitrate(mgN/l)	.103±.014	.390	0.0	.546±.09	1.8	0.0	2.40±.05	2.40	2.20	2.75±.45	3.40	2.10
Nitrite(mgN/l)	.003±.001	.010	0.0	.610±.099	2.9	0.0	1.77±.25	2.40	1.40	2.47±.42	3.50	1.80
Total Nitrogen(mgN/l)	.668±.089	3.30	.10	1.59±.65	30.0	0.16	18.4±8.5	30.0	6.70	20.7±15.0	37.0	4.40
Cu (ug/l)	2.65±46	8.0	0.0	33.8±23	600	0.0	25±21.2	40	10	26.5±26	45	8
Zn (ug/l)	14.0±4.9	110	0.0	26.8±4.8	110	0.0	45±20	60	30	80±40	120	40
Cd (ug/l)	.136±.074	1.0	0.0	.08±.05	1	0.0	0			0		
Cr (ug/l)	3.14±.95	10.0	0.0	6.2±1.7	30	0.0	1.0±.7	2	0.0	0		
Pb (ug/l)	.64±.26	5.0	0.0	1.16±.2	4	0.0	0			0		
Ni (ug/l)	3.47±.79	12.0	0.0	4.84±.57	9	0.0	0			0		
Fe (ug/l)	39.4±9.3	270	0.0	56.6±13.3	470	0.0	150±62	290	10	195±70	360	40
Ba (ug/l)	63.2±24	500	0.0	59.2±15.7	300	0.0	150±31	200	100	200	200	200
Al (ug/l)	20±4.1	120	0.0	20.0±4.5	110	0.0	77±45	180	0.0	100±25	160	50
Mn (ug/l)	4.79±1.3	30	0.0	103±15.6	320	0.0	7.5±2.5	10	0.0	93±70	260	10

(1) perennial
(2) ephemeral

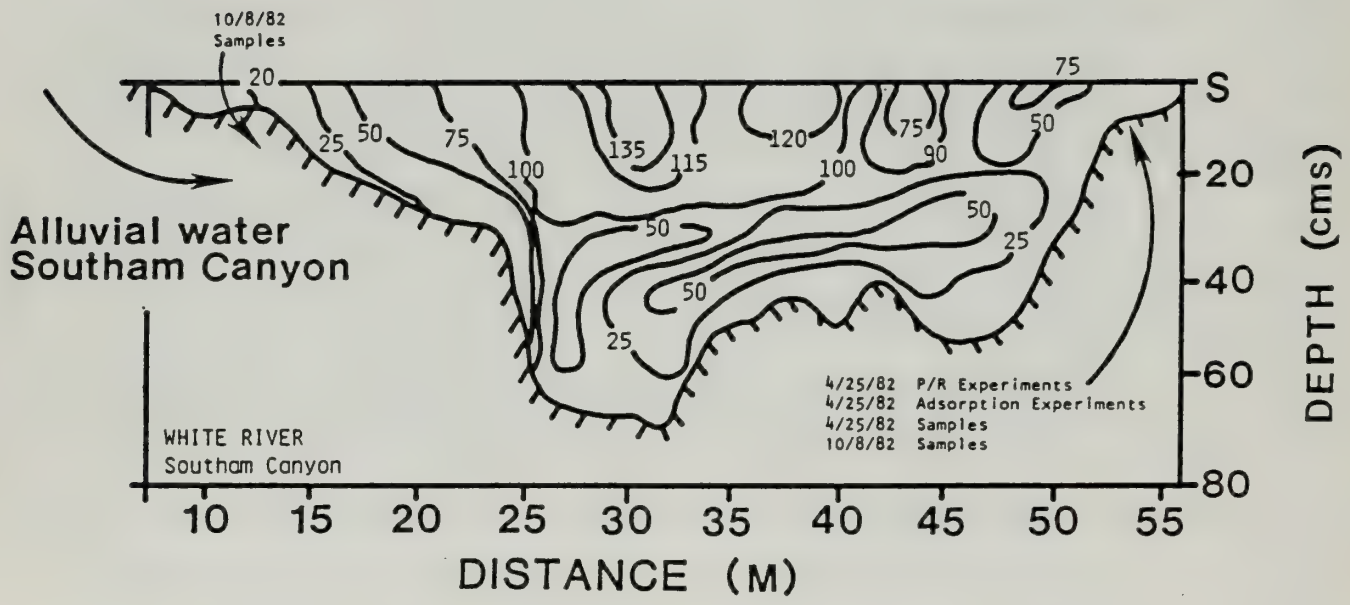

Figure 7.2-9. Cross-section profile and velocity contours (m/s) of WRSOC monitoring transect WR18. Locations of samples and experiments are shown as well as entry point of Southam Canyon alluvial water (south bank).

Table 7.2-8. The concentration of selected water quality parameters from alluvial wells in major drainages to the White River. (Source: WRSOC 1977)

	Alluvial Wells											
	White River (A6-1-1 upper)			Evacuation Creek (A6-8)			Southam Canyon (A6-6-2 upper)			Asphalt Wash (A6-3-3 upper)		
	mean±S.E.	max	min	mean±S.E.	max	min	mean±S.E.	max	min	mean±S.E.	max	min
Total Alkalinity($mgCaCO_3/l$)	319±44	363	274	427±18	456	320	296±9	323	271	470±8	497	445
Dissolved Solids(mg/l)	951±29	980	921	3877±46	410	3650	3506±352	4490	2420	3340±153	3630	2680
Total Hardness(mg/l)	425±25	450	400	1171±29	1300	1100	1760±200	2300	1100	1388±105	1600	930
pH(units)	7.9±.14	8.1	7.7	7.9±.1	8.4	7.4	7.6±.1	7.8	7.4	7.8±.1	8.0	7.6
Conductance(umhos/cm)	1467±174	1750	1300	4550±230	5200	3100	4260±352	5000	3000	4132±150	4400	3490
Sulfide(mg/l)	0	0	0	0.7±.04	1.1	0.9	0	0	0	.7±.5	1.3	0.0
Dissolved Organic Carbon(mg/l)	33±5	39	27	16.6±.3	17	16	8.5±.9	11	6	23±1	25	21
Orthophosphate(mgP/l)	.005±.001	0.01	0.0	.007±.002	0.01	0.0	.020±.004	0.04	0.0	.010±.002	.02	0.0
Total Phosphorus(mgP/l)	3.11±2.79	5.90	0.31	2.87±1.32	7.40	0.21	2.89±2.24	8.70	0.46	1.11±.22	1.90	0.48
Ammonia(mgN/l)	0.54±.01	0.56	0.52	.094±.018	0.14	0.04	0.08±0.02	0.14	0.01	0.67±.01	0.74	0.54
Nitrate(mgN/l)	0.24±.01	0.26	0.22	0.13±.015	0.17	0.07	0	0	0	0.08±.02	0.22	0.01
Nitrite(mgN/l)	0.25±.01	0.27	0.23	.016±.005	0.07	0.0	0.30±.05	0.38	0.16	0.03±.01	0.16	0.0
Total Nitrogen(mgN/l)	6.1±2.5	9.8	2.4	18.5±12.1	70.0	1.5	1.67±0.60	3.30	0.63	2.60±0.5	4.6	1.1
Cu (ug/l)	3.5±.5	4	3	3.2±.6	5	1	10±3.5	18	3	4.0±1.8	11	1
Zn (ug/l)	10±1	10	10	10±4	20	0	3700±424	4600	2500	40±11	80	20
Cd (ug/l)	0	0	0	0	0	0	1.8±.8	4	0	0.4±.2	1	0
Cr (ug/l)	350±299	650	50	176±78	500	60	158±50	320	70	64±10	80	30
Pb (ug/l)	0	0	0	0	0	0	3.3±2	9	0	2.4±1.7	9	0
Ni (ug/l)	--	--	--	--	--	--	2	2	--	--	--	--
Fe (ug/l)	30±9.8	40	20	50±11.6	100	20	28±4	40	20	245±105	650	20
Ba (ug/l)	150±122	300	0	40±25	100	0	100±100	400	0	0	0	0
Al (ug/l)	25±14	40	10	24±2.2	30	20	20±4	30	10	22±6	40	0
Mn (ug/l)	425±42	470	380	780±123	1200	470	2120±168	2500	1500	410±29	460	300

taken from the side of the river adjacent to alluvial fans compared to the non-alluvial sites (Figure 7.2-10 and Table 7.2-9). Furthermore, specific metals which were high in the alluvial water were correspondingly high in the river biocenosis adjacent to this source.

B. Metal Transformation Mechanisms It has been noted that certain physical-chemical characteristics of a water body can substantially affect the metal ion concentrations within the water and therefore, the subsequent effect of the metal upon organisms (Figure 7.2-11). Dissolved oxygen and temperature (Lloyd 1965), pH (Whitley 1968), redox potential (Reinhart and Forstner 1976), hardness (Schweiger 1956), organics-metal ion interactions (Sprague 1968), complexation (Brown and Shaw 1974), and the chemical characteristics of the individual metal species (Stumm and Morgan 1970) have been considered to be dominant factors in determining the effects of heavy metals on organisms. Furthermore, several studies have noted that biotic factors may play an important role in determining the response of an aquatic community to heavy metal enrichment. Factors such as the organisms' life cycles (Lovett et al 1972), seasonal variations induced by primary producers (Morris 1971), contamination of food (Flegal and Martin 1977), and the mobility of the organism (Nisimura 1974) have been shown to be important. It is believed that the observed concentrations of metals in the abiotic and biotic components of the White River ecosystem are the result of many, if not all of the above factors. A specific discussion relative to each compartment will further investigate these possible mechanisms in later sections of this report.

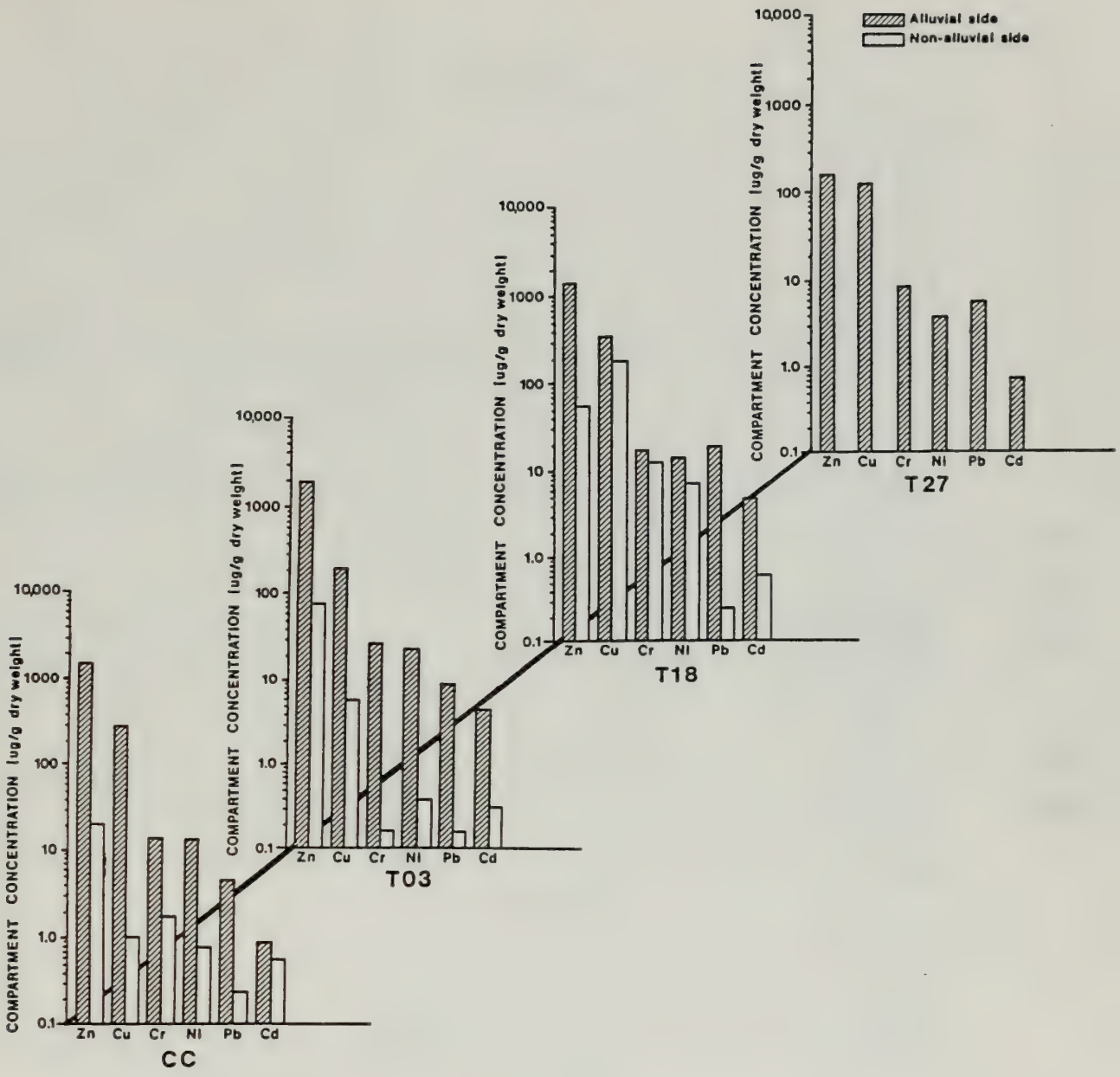

Figure 7.2-10. The concentration of metals in macroinvertebrates at four sites in the White River on 10/8/82. The data compares alluvial and nonalluvial sides of the river.

Table 7.2-9. A two-way analysis of variance for metals in White River macroinvertebrates when compared between three river transects (near Cowboy Canyon, near Evacuation Creek and near Southam Canyon) and within transect locations (adjacent to alluvial fan and opposite side of alluvial fan). Data was collected on 10-8-82.

	METALS											
	Cadmium		Chromium		Copper		Lead		Nickel		Zinc	
Locations	F	P	F	P	F	P	F	P	F	P	F	P
Between Transects	1.16	0.46	0.12	0.89	4.56	0.17	21.38	0.04**	82.64	0.01**	0.6	0.62
Within Transects	13.24	0.06*	1.43	0.35	18.13	0.05*	38.44	0.02**	331.57	0.003***	8.53	0.10*

* $P \leq 0.1$

** $P \leq .05$

*** $P \leq .01$

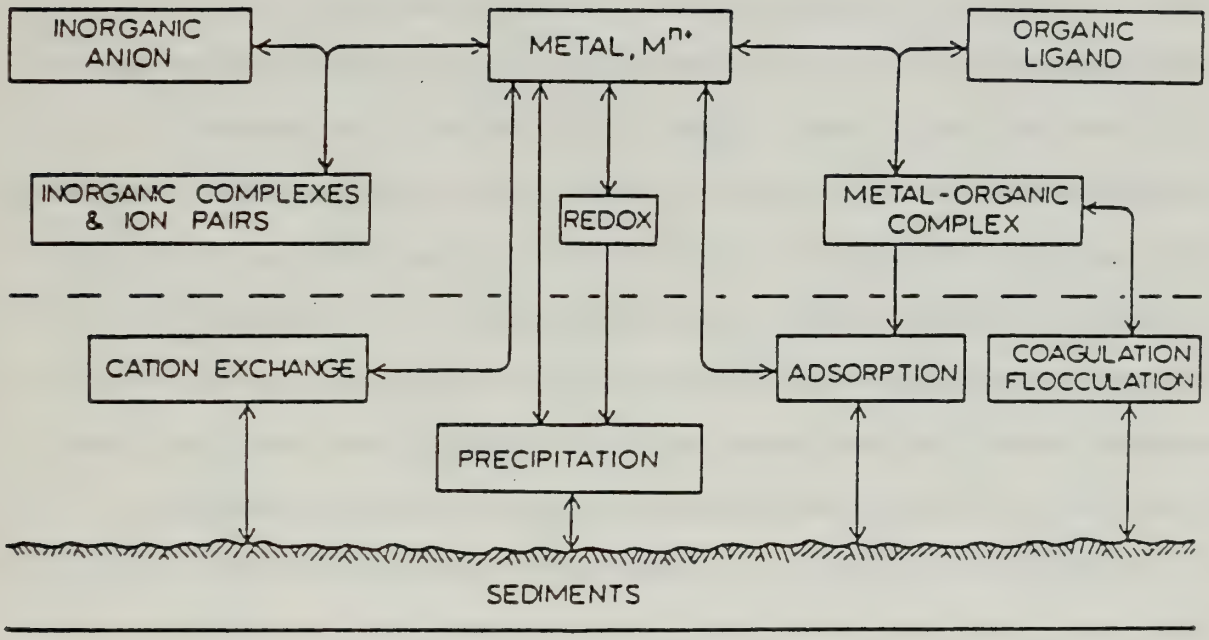

Figure 7.2-11. The natural phenomena which may affect the concentrations of heavy metals in natural environments.

While data concerning actual speciation of metals in the White River are not available at the present time, previous research (Medine 1983) indicated the potential importance of $CaCO_3$ precipitation, adsorption phenomena and inorganic and organic complexation in terms of regulating soluble metals in the Colorado River and tributaries. Mass balance calculations for Lake Powell (downstream of the White River) indicated that Fe, Cu, Zn, Pb and As were 70% removed from the inflow tributaries by Lake Powell and that Se, Cr and Ni were removed to lesser degrees (40%, 15% and 8%, respectively. Calculations performed with MINEQL (Westall et al. 1976) indicated that the White and other Colorado River tributaries were supersaturated with $CaCO_3$, $Ca_5(OH)(PO_4)_3$, $ZnSiO_3$, $Fe(OH)_3$, $Ba_3(AsO_4)_2$, $Pb(OH)_2$ and $Cu_2(OH)_2CO_3$ thus implicating precipitation or coprecipitation of metals as an important regulatory mechanism. Additional reactions (complexation, redox) may also explain why Se, Cr and Ni were removed to lesser extents than the other metals in Lake Powell. However, it appears the adsorption/desorption was a dominant mechanism controlling the transformation process and ultimate fate in this river system. It is not known whether Cr is present as a hexavalent or trivalent ion although a reasonable hypothesis based on the above results might anticipate a significant fraction of Cr occurring as Cr(VI). Cr(VI) in sediment-water systems has been removed to a lesser degree than Cr(III) as noted in previous research (Medine and Porcella 1980, Medine and Conway 1982) although significant adsorption of Cr(VI) would occur following reduction to Cr(III). The implications of metal speciation will be expanded upon in the following discussion of metal fates.

C. Metal Fate -- Inorganic Phase (Calcium Carbonate and Fine Detritus-Sediments) The coprecipitation or adsorption of trace metals with calcium carbonate has been documented in the literature (Patchineelam 1975). In the White River, the $CaCO_3$ precipitate contained substantial amounts of metals (Tables 7.2-2 and 7.2-5). Chrome was in the highest concentration of the metals studied while cadmium was the least concentrated. Experiments have been conducted on the precipitation dynamics of copper during base flow water quality conditions (Medine et al. 1984). These data (Figures 7.2-12 and 7.2-13) indicate that a direct linear relationship exists between the initial metal concentration in the aqueous phase and the amount precipitated. A further inspection of the fine detritus in inorganic sediments (which also contained $CaCO_3$ particles as well as other minerals) indicated the same pattern. The magnitude of the metal concentrations in this inorganic phase (Table 7.2-2) when compared to literature values (Table 7.2-10) indicated that chrome and nickel were in concentrations equal to or above those in contaminated systems. Cadmium and copper, although higher than naturally occurring values in other systems were not in concentrations equal to contaminated river sediments. Lead and zinc were equal to natural concentrations from other uncontaminated systems.

In Table 7.2-11, the concentration factors (water to sediments) based upon the average dissolved metal concentrations in the White River from 1949-1982 (WRSOC 1982) matched the sequence of divalent metal concentrations (Pb>Cu>Ni>Zn>Cd) found by Mitchell (1964) and Reynolds (1935). It appears that Pb, which had the highest concentration factor in the inorganic phase (precipitates and sediments), and the lowest concentration in the water, has

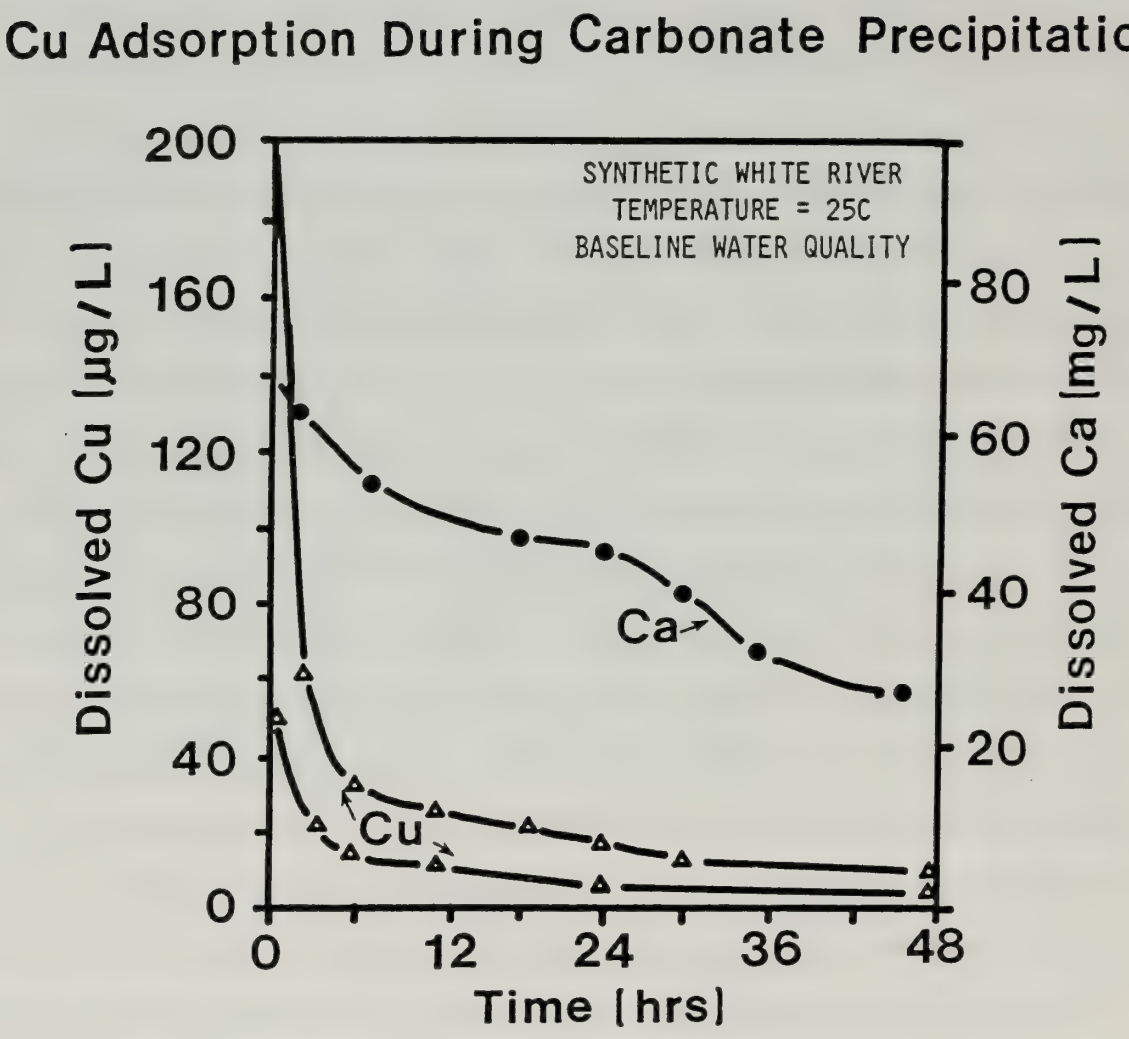

Figure 7.2-12. The relationship between dissolved copper concentrations and time in the presence of precipitating $CaCO_3$ in the White River.

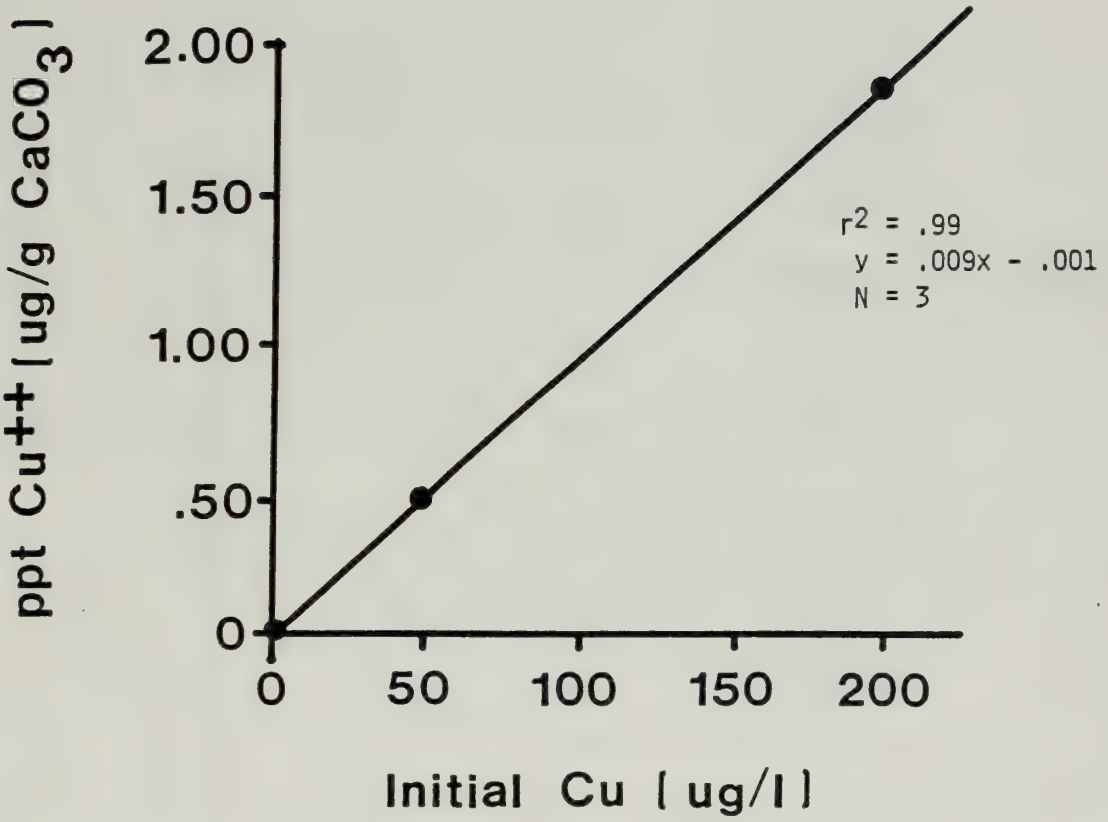

Figure 7.2-13. The relationship between the initial copper concentration and the amount of copper precipitated from White River water.

Table 7.2-10. The concentrations of Cd, Cr, Cu, Pb, Ni and Zn for various components of the aquatic ecosystem from selected studies.

Ecosystem Site	Geographical Location	Metal Concentration ug/g dry weight Cd	Cr	Cu	Pb	Ni	Zn	Reference
Inorganic phases								
Sediments	Menominee River (Michigan)							
	background	0.1	10.5	10.0	143	8.2	124	Lee et al. (1982)
	contaminated	9.3	23.7	37.0	315	19.9	230	
Sediments	River Etherow(England)							
	background	2.4	9.6	10.0	54	--	74.0	Say et al. (1981)
	contaminated	23.0	99.6	72.0	200	--	4960	
Sediments	Swiss Rivers							
	background	~0.3	--	--	~50	--	~75.0	Vernet et al.
	contaminated	≤ 9	--	--	100-300	--	225-750	(1977)
Sediments	Lake Powell							
	background	2.55	19.2	--	60.0	--	12.5	Medine & Porcella
	contaminated(lab)	4.60	42.0	--	104.0	--	266	(1980)
Organic phases (periphyton)								
Cladophora	Vermillion River (Illinois)							
	background	--	--	--	14.9	46	--	Leland and McNurne
	contaminated	--	--	--	347	265	--	(1974)
Cladophora	Lake Ontario							
	background	1.4	--	6.4	12.2	--	8.2	Keeney et al.
	contaminated	3.9	--	7.2	9.5	--	23.7	(1976)
Cladophora	Leine River/FRG							
	background	0.29	--	9.1	5.2	11.9	62	Abo-Rady (1977)
	contaminated	0.94	--	23.0	49.2	23.8	190	
Organic phase (macroinvertebrates)								
Asellus	Elsenz River (F.D.R.)							
	background	0.47	--	8.64	2.69	--	119	Prosi (1977)
	contaminated	2.97	--	19.91	16.50	--	203	
Brachycentrus	Sacramento River (California)							
	background	< 2.0	--	159	--	--	92	Zanella (1982)
	contaminated	5.8	--	155	--	--	682	
Hydropsyche	Sacramento River (California)							
	background	<2.0	--	168	--	--	178	Zanella (1982)
	contaminated	5.5	--	241	--	--	1096	
Gammarus	River Werra and Weser	0.18-0.77						Zauke (1982)
Organic phase (fish)								
Blue gill	Skinface Pond (So. Carolina)	--	--	2.15	1.10	--	142	Wiener and Giesy (1979)
Warmouth	Skinface Pond (So. Carolina)	--	--	2.04	0.80	--	103	
Largemouth bass	Skinface Pond (So. Carolina)	--	--	1.88	0.50	--	75	
Redfin pickerel	Skinface Pond (So. Carolina)	--	--	2.77	1.10	--	216	
Lake chubsucker	Skinface Pond (So. Carolina)	--	--	2.64	0.40	--	79	
Shorthorn sculpin	Strathcona Sound (Northwest Territories)	1.0-1.6	--	1.6-9.9	0.1-1.2	--	28-100	Bohn and Fallis (1978)
Artic Char	Strathcona Sound(Northwest Territories)	1.6-2.3	--	1.1-4.2	0.2-0.5	--	14-33	

Table 7.2-11. The concentration factors from water into each major component of the White River ecosystem. Data collected on 4-25-82.

Concentration Factors

Metal	Inorganic		Organic				Highest ↔ Lowest
	ppt	Sediments	Coarse Organics	Peri-phyton	Macro-invertebrates	Fish	
Ni	.58	.71	.71	.69	1.36	.17	$M > C \geq S > P > P_t > F$
Cr	1.20	2.10	.92	1.90	2.30	.25	$M > S > P > P_t > C > F$
Cd	.42	.77	1.80	.94	9.50	1.42	$M > C > F > P > P_t > S$
Pb	1.60	5.56	2.70	3.50	3.18	.38	$S > P > M > C > P_t > F$
Cu	.64	.72	4.60	.55	3.50	.70	$C > M > S > F > P > P_t$
Zn	.17	.56	1.50	.59	1.96	1.40	$M > C > F > P > S > P_t$
Highest	Pb	Pb	Cu	Pb	Cd	Cd	
↕	Cr	Cr	Pb	Cr	Cu	Zn	
	Cu	Cd	Cd	Cd	Pb	Cu	
	Ni	Cu	Zn	Ni	Cr	Pb	
	Cd	Ni	Cr	Zn	Zn	Cr	
Lowest	Zn	Zn	Ni	Cu	Ni	Ni	

the ability to preferentially compete for exchange sites on the sediment clays and desorb other metals such as Cd and Zn (Soong 1974). The general sequence in order of decreasing ability to exchange is Pb>Cr>Cu>Ni>Zn>Cd. This represents the same sequence observed in the concentration factors.

One of the overriding fates of metals entering the White River system appears to be the adsorption onto suspended materials and their deposition into the stream sediments. The quantitative description of heavy metal adsorption and desorption has been and is currently an area of intensive research activity. It is generally understood that descriptions of metal pathways, speciation and fates must include the role of adsorption in the regulation of metal concentrations. Heavy metal accumulation by sediments and suspended matter occurs by physical-chemical adsorption, biological uptake and by physical accumulation. The physical-chemical adsorption on suspended particles and the concurrent sediment accumulation or enrichment appears to be the major mechanisms by which periodic metal loads are attenuated in the White River.

The difficulty in developing quantitative models to describe adsorption/desorption in natural environments is due to the complexity of natural sediments and particulates, the effect of inorganic and organic ligands upon adsorption, the metal species distribution, and other physical-chemical attributes of the environmental system (pH, adsorbent concentration, etc). To overcome some of this difficulty, adsorption studies using "model" surfaces (clays, Al_2O_3, $Fe[OH_3]$, MnO_2) have been performed and have provided an important understanding of the mechanisms involved. A considerable amount of work has been reported on the adsorption of metals by

clays (Jenne 1977, Farrah et al. 1980) although some evidence indicates that clays naturally exist as substrates coated with metal oxides or organic matter (Bourg 1982).

Additionally, work with metal oxides (Dempsey & Singer 1980, Benjamin and Leckie 1981, Elliott and Huang 1979) has resulted in considerable advances in the understanding of metal uptake mechanisms. Complexation of metal ions by inorganic and organic ligands can have a considerable impact on the adsorption by solid surfaces with the result showing an enhancement, suppression or no effect upon metal adsorption (Benjamin and Leckie 1981, Elliott and Huang 1980). Metal adsorption studies using real sediments (Brown 1979, Sholkovitz and Copeland 1981, Gardiner 1974) can provide hints about potential adsorption mechanisms and statistical correlations between particular sediment parameters and the metal mass adsorbed, but cannot give detailed information on the operative mechanisms. It is clear that further work is necessary to quantitatively describe the adsorption process in natural systems. A series of preliminary absorption experiments were conducted in the White River with Pb, Cu and Zn (representing high and low sediment/metal concentrations, from Table 7.2-11). These suspended sediment experiments (Medine et al. 1984) were conducted in situ using reaction chambers, with natural water and sediments from the White River. The data indicated that metal removal was very rapid (<1hr.) and that increasing particulate concentration and pH were important factors in reducing equilibrium concentrations of the metal (Figures 7.2-14 and 7.2-15). Furthermore, a comparison of the concentration factors for White River sediments (Table 7.2-11) indicated that Pb would be removed to a greater

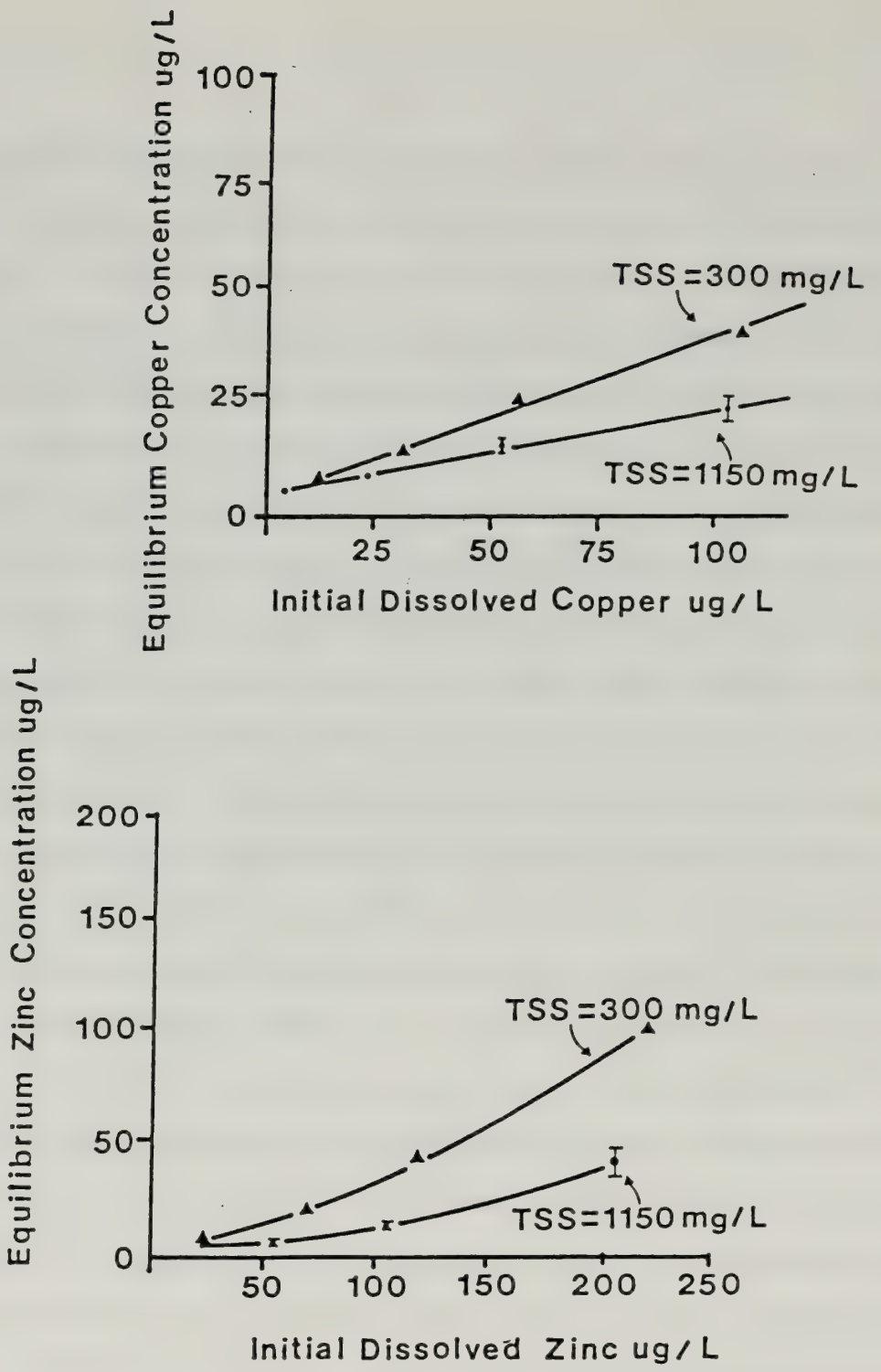

Figure 7.2-14. The effect of initial copper and suspended solids on the 24 hr equilibrium dissolved Cu (Top) and the effect of initial zinc and suspended solids on the 24 hr equilibrium dissolved Zn (Bottom) during field experiments on the White River. The reactor volume was 8 liters and temperature was maintained at ambient river temperature.

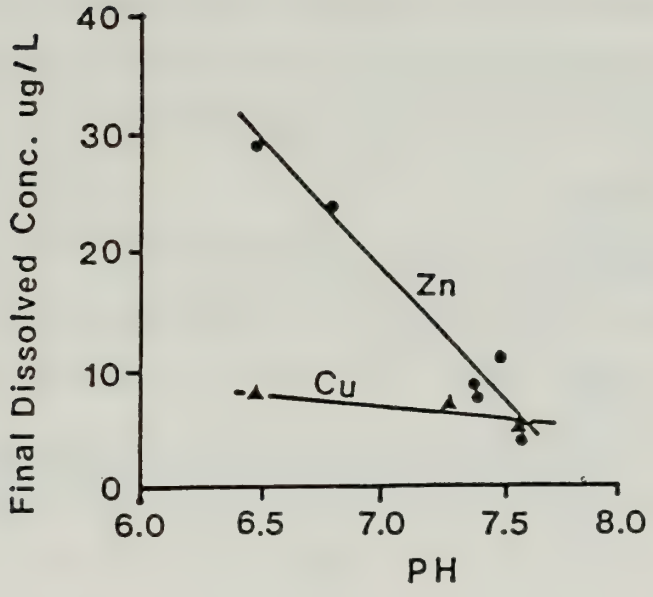

Figure 7.2-15. The effect of pH on the equilibrium level of Cu and Zn during field experiments on the White River. Desorption was highly significant for Zn. The initial levels of dissolved metal were 5 ug/l for both metals.

extent than Zn. The results from the in situ adsorption study substantiated this conclusion (Figure 7.2-16).

D. Metal Fate-Organic Phase The passive movement of heavy metals onto detrital organics by adsorption has been investigated by Rashid (1974) and Jonasson (1977). In general, the sequence of highest to lowest concentration factors, based upon literature values are: Pb>Cu>Cd>Ni>Zn.

This sequence corresponds to the observed values from the White River (Table 7.2-11) for the coarse detritus-organic phase. The similarities in these two sequences may indicate that the concentration of metals in this organic compartment may be the result of the dissolved metal concentrations and the adsorption ability and/or complex stability of the individual metal species.

Aquatic organisms have a requirement for certain essential metals (Cu and Zn), while some metals (Cd, Cr, Pb and Ni) are considered nonessential. Recent studies (Davis 1973, Vancutsem and Gillet 1982, Harding and Whitton 1981) have shown that the uptake of certain heavy metals by aquatic plants was initially a passive process of adsorption onto the cell walls. The actual uptake was controlled by the rate of diffusion into the cell. The concentration of metals in the periphyton (Cladophora sp.) from the White River indicated that all the metals studied were higher than previously determined background levels from uncontaminated systems (Table 7.2-10). In several cases (Abo-Rady 1977, Kenney et al. 1976) the background concentrations in the White River were higher than contaminated sites. It should be noted, however, that Leland and McNurney (1974) reported concentrations of Ni and Pb in Cladophora sp. taken from a contaminated

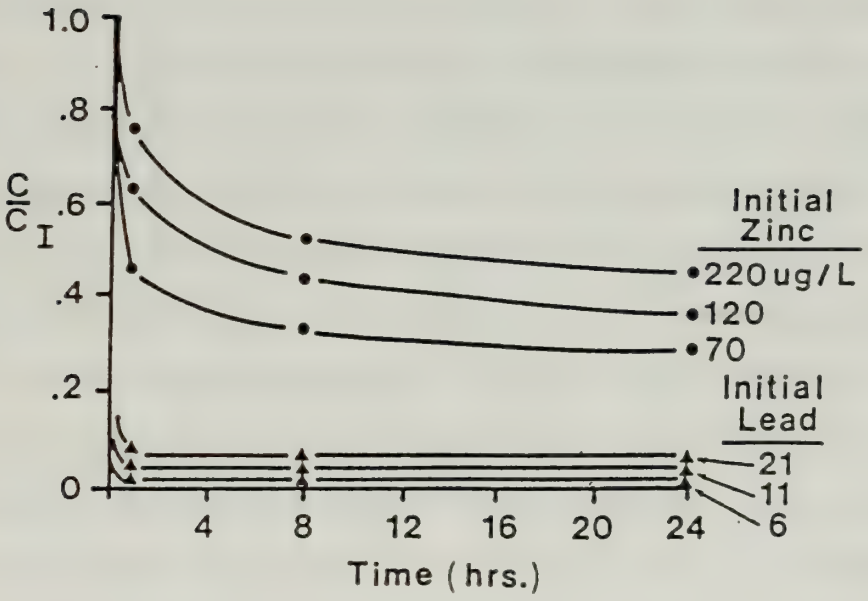

Figure 7.2-16. Adsorption vs. time for three levels of Pb and Zn during field experiments on the White River in November, 1982. Each reactor volume = 8 liters.

section of the Vermillion River, Illinois that were 10 times higher than those reported in this study. The concentration factors (Table 7.2-11) for the organic phase are comparable to other literature values (Medine and Porcella 1980). As noted above, the sequence of decreasing concentration factors corresponded to the sequence of decreasing passive adsorptive abilities of the specific metals onto organic materials.

Unlike the plants which were previously discussed, there are several ways in which heavy metals can be introduced into animals. In general, there are three basic mechanisms: (1) direct uptake via skin or gills, (2) adsorption onto body tissues, and (3) from food.

It should be noted that the macroinvertebrate trophic level in this study contained a variety of organisms with different food sources. Detritivores, herbivores, omnivores and carnivores were included. However, in each case the food types eaten by these macroinvertebrates contained significantly higher levels of metals when compared to the water. Furthermore, several of the dominant species from this trophic level were constantly in direct contact with the sediments (where elevated metal concentrations were detected). It was believed that because of these factors and the apparent lack of a homeostatic controlling mechanism (i.e. excretion), this trophic group had the highest metal concentration factor (except for Pb) relative to the water (Table 7.2-11). These results are consistent with the findings of Bryan and Hummerstone (1971) and Ayling (1974). Cadmium, which had the highest concentration factor, was found to be substantially higher than reported literature values for macroinvertebrates in contaminated rivers. Zinc was found to be above background levels;

whereas, Cr, Cu, Pb and Ni are comparable to other natural background values.

In comparison to literature values (Table 7.2-10), the whole body metal load in fish from the White River contained substantially higher levels of all metals when compared to other uncontaminated rivers. Experimental studies have indicated that in most cases the rates of metal uptake in fish have been related to the concentrations in the water (Pentreath 1973) and (more importantly) to the metal concentrations in the food (Hoss 1964, Renfro et al. 1974, Delisle et al. 1975). However, numerous studies have also shown that there is no certainty that the concentrations in the fish will reflect those of the environment regardless of the metal source (water or food). This is especially true for such metals as copper and zinc where excretion or some sort of regulatory mechanism has been shown to exist (Mount 1964, Brung et al. 1973, Fromm and Stokes 1962). Non-essential metals such as Cd, Ni, Cr, and Pb are not as well regulated and can accumulate to levels 10^3 to 10^4 times the levels observed in the water (Table 7.2-11).

E. Metal Trophic Level Accumulations An attempt has been made in the previous section to quantitatively describe the transport, transformation and fate of heavy metals in the White River ecosystem adjacent to the Federal Lease Tracts Ua-Ub. There are conflicting results from studies which center around the concept of food chain enrichment with heavy metals. The results presented here appear to agree with the findings of Enk and Mathis (1977). Table 7.2-11 and Figure 7.2-17 indicate that to a certain extent, metal concentrations within the trophic structure were accumulated through the food chain, especially for non-essential metals. The major sequence in decreasing concentrations by trophic group were:

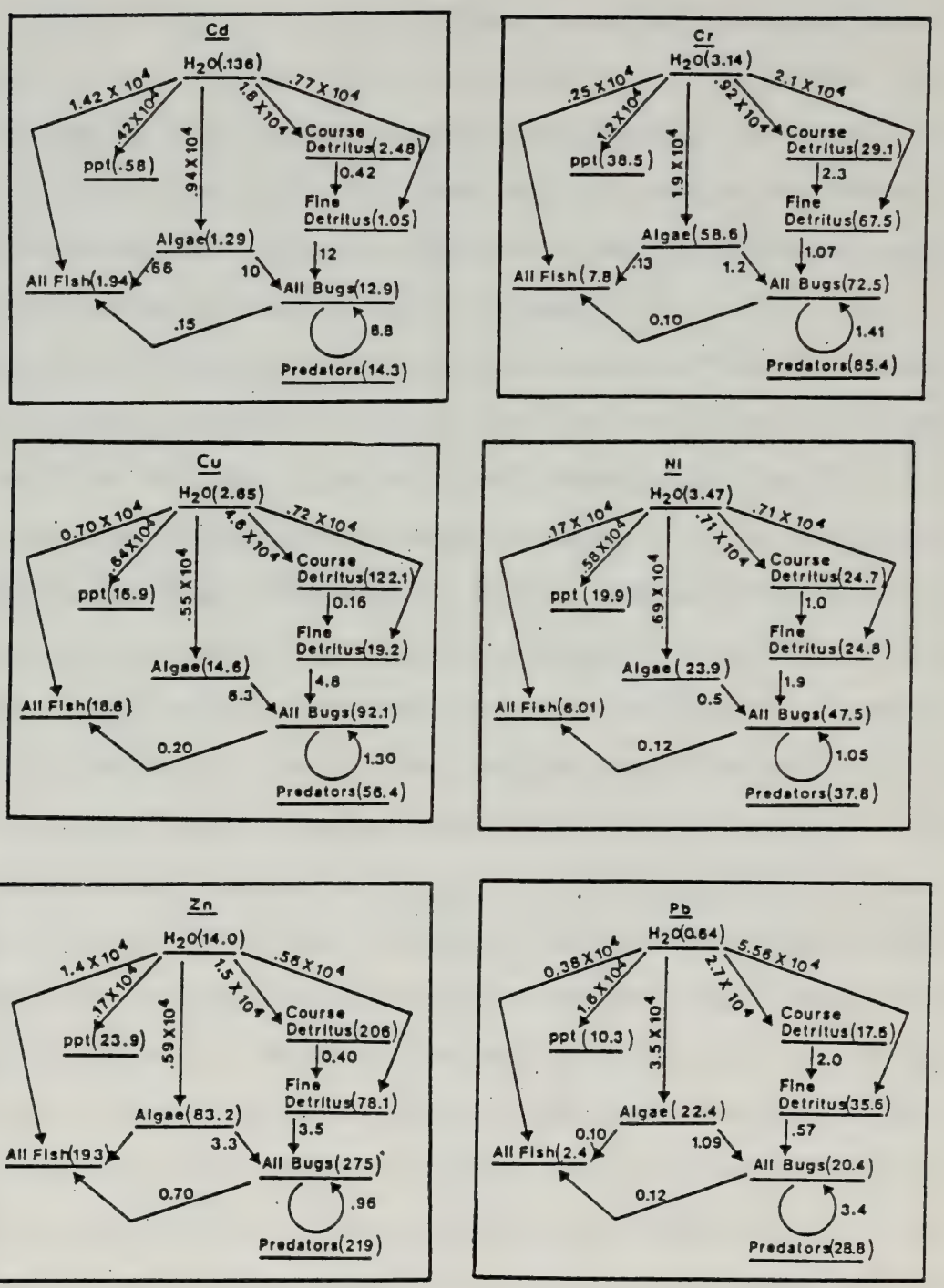

Figure 7.2-17. The trophic level accumulations for the selected heavy metals studied in the White River. Numbers in parenthesis ( ) represent ug/g d.w. While numbers by the arrows are concentration factors.

macroinvertebrates>coarse detritus>periphyton>sediment>precipitate>fish

Although the species of metals studied exhibited food chain enrichment to various degrees, macroinvertebrates generally had the highest concentration and fish the least. The interrelationship between metal content in the surrounding environment (water, sediment, etc.) and the ability to bioregulate both essential and nonessential metals appear to be important regulating factors. Although demonstrating major differences in concentrations a strong relationship was found between the metal content in macroinvertebrates and precipitates for all metals except chromium and copper (Table 7.2-12 and Figure 7.2-18). These data indicate that the precipitates in the White River appear to reflect long term site-specific water quality; whereas the macroinvertebrates, although having the same trends, tend to amplify the short term metal events (periodic loads).

F. Critical Pathway or Process Identification Few studies have attempted to describe the critical pathways in an ecosystem by defining the in situ response of the system to experimental pollutant loads. Gachter (1979) attempted such a study in a lake ecosystem, while Medine et al. (1980) documented a laboratory ecosystem response to heavy metal loads. Carter and Lamarra (1983) demonstrated that the use of community production and respiration rates were significant and sensitive indicators to external perturbations. Furthermore, it appeared that the in situ response from different systems to the same perturbation was dependent upon site-specific

Table 7.2-12. The regression equations between the metal concentrations in precipitates and macroinvertebrates in the White River. Data collected on 4-25-82 and 10-8-82 10-8-82.

Element	Equation (y=ax+b) (1)	N	r^2	Significance Level
Lead	y = 2.57x-12.51	8	.93	.01
Cadmium	y = 62.3x-24.57	8	.94	.01
Nickel	y = 7.89x-79.60	8	.83	.01
Zinc	y = 120.3x-2870	8	.49	.05
Chromium	y = 2.69x-48.78	8	.40	NS (2)
Copper	y = 13.45x-53.38	8	.27	NS (2)

(1) y = macroinvertebrate concentration (ug/g dry weight)
x = precipitate concentration (ug/g dry weight)

(2) NS = not significant

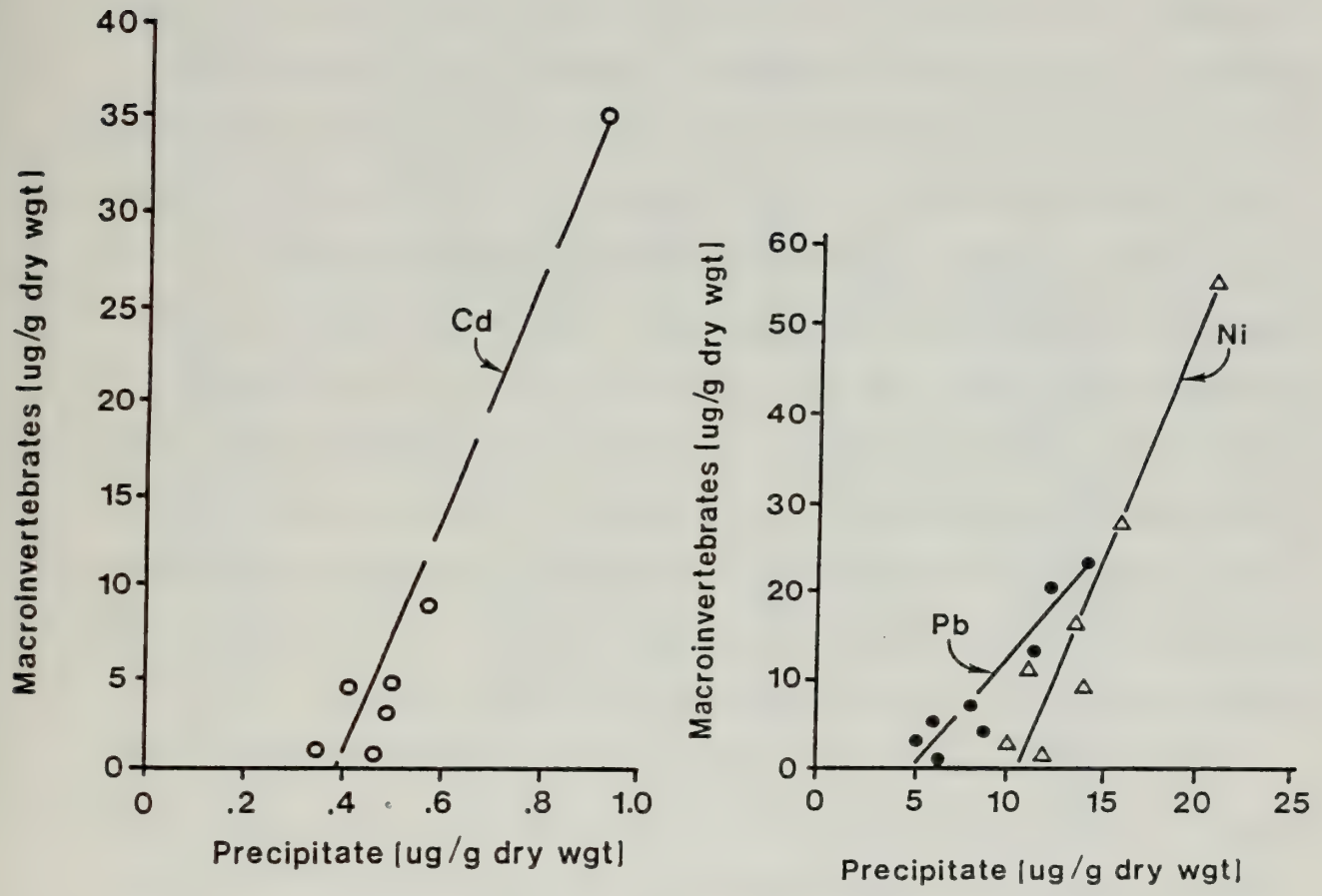

Figure 7.2-18. The relationship between macroinvertebrate metal content and precipitate metal content for all sites in the White River. Data was collected on 4-25-82 and 10-5-82.

characteristics. A similar preliminary experiment was conducted in the White River (11-3-82 to 11-5-82) and has been reported by Medine et al. (1983). During this experiment, four chambers were used with the following treatments: (1) no additions (control), (2) EDTA ($5x10^{-7}$ M), (3) low metal additions, and (4) high metal additions. The results of the control run (first 24 hours) and the experimental run with additions can be seen in Table 7.2-13. EDTA addition and the control chamber with no additions were similar on both days. Low metal additions stimulated net production, gross production and respiration, and high metals inhibited net production and stimulated respiration. The metal concentrations (Pb, Cu and Zn) were reduced within the chambers during the 24 hours of the experiment from the initial levels (Table 7.2-14). Pb was reduced to below detectable levels within 8 hours after the start of the experiment. The results indicated that the White River ecosystem may have adapted to periodic natural metal loads it receives and that the community response can be quantified.

There are numerous examples in the literature where organisms have been shown to increase their tolerance to the toxic effects of some metals. Fish (Sinley et al. 1974), macroinvertebrates (Saliga and Ahsanullah 1973), and algae (Morris 1972) have provided several examples of this possible mechanism. It has been suggested that their tolerances may be genetically determined; however, the evidence at the present time is incomplete (Bryan and Hummerstone 1973).

A second possible mechanism of adaptation may be the temporal distribution of organisms within the White River system. Zanella (1982) noted a change in species composition within the macroinvertebrate community

Table 7.2-13. The net production, respiration and gross production estimates from the control and treatment chambers in the White River, Utah. Experiments were conducted between 11-3-82 and 11-5-82.

Control Run (mg O_2/m^2/day				With Additions (mg O_2/m^2/day		
Net	Respiration	Gross	Treatments	Net(%)*	Respiration(%)	Gross(%)
810	317	1036	#1 No Additions	951(117%)	317 (100%)	1177(114%)
647	306	867	#2 EDTA	768(119%)	330 (109%)	1004(116%)
741	298	954	#3 Low Metal	964(130%)	304 (102%)	1181(123%)
354	165	453	#4 High Metal	311(88%)	237 (144%)	453(100%)

*% - represents the % of the control with the control being expressed as the previous days production-respiration experiment. 100% indicates that the control and treatments were equal.

Table 7.2-14. The soluble concentrations of Pb, Cu and Zn in the experimental production/ respiration chambers in the White River, Utah between 11-3-82 and 11-5-82.

Soluble Metal Concentrations (ug/l)

Treatment	Pb^{+2} (ug/l)			Cu^{+2} (ug/l)			Zn^{+2} (ug/l)		
	Initial	8hrs	24hrs	Initial	8hrs	24hrs	Initial	8hrs	24hrs
No Additions	1.0	<0.5	<0.5	7.0	7.0	7.6	25.0	11.5	10:3
EDTA	1.0	<0.5	<0.5	7.0	5.6	4.6	25.0	11.0	9.6
Low Metals	6.0	<0.5	<0.5	32.0	14.0	13.0	75.0	22.0	13.2
High Metals	21.0	4.5	<0.5	107.0	30.0	36.0	225.0	54.0	30.5

structure over a 15 year period as a result of low level metal pollution. The two organisms described in that study were also found in the White River. The distribution of these two species over time in the White River indicated that the more resistant species, an invertebrate, Hydropsyche sp., was present when water quality was potentially at its worst during base flow conditions; whereas, the less resistant species was present only during upper basin runoff when the best water quality conditions occurred.

A third possible mechanism, the adsorption and desorption of the soluble metals with suspended sediments, was investigated simultaneously with the P/R experiments (Medine et al. 1983) and have been summarized here. These data indicate that the suspended sediments within the White River can substantially and rapidly reduce the concentrations of dissolved heavy metals. Adsorption of metals into the organic phase including algae and coarse detritus may also be an important factor in the removal of metals from solution and its concurrent increase in the phase of macroinvertebrates. The consistent levels of metals in the inorganic precipitate and sediments and fish compartments with distance downstream (Figures 7.2-3, 7.2-4 and 7.2-5) and the similarities in the sequences of adsorption ability of the metals compared to the concentration factors, may indicate that adsorption-desorption has regulated the concentration of metals in the White River between storm events.

It is important to note, that although the White River maintains a diverse and productive ecosystem, the metal concentrations present within the trophic structure are elevated above literature background levels. The exact mechanisms (genetic shifts, organism tolerance, spatial and temporal

separation and the role of suspended sediments) by which this community can maintain its structure and function require further investigation.

7.3 VEGETAL AND SOIL CHARACTERISTICS INFLUENCING RODENT POPULATIONS

7.3.1 Introduction

The general habitat preferences of many rodents have been documented by the last several generations of ecologists and natural historians. Food preference with associated morphological characteristics of rodents are usually the parameters evaluated in elucidating habitat selection (Baker 1971; Price 1978). However, additional environmental parameters that characterize habitat preference by rodents are vegetation, soils, and water, the major extrinsic factors that influence rodent populations (Hardy 1945; Feldhamer 1979; Kitchings and Levy 1981). The change in rodent populations with the concurrent alteration of vegetal habitat is well documented (Grant et al. 1977; Hansen and Warnock 1978; Van Home 1981; Hanley and Page 1982; McGee 1982; Parmenter and MacMahon 1983). In addition, small mammal research in relationship with plant succession has shown the importance of vegetal architecture to rodent populations (Anderson et al. 1980; Langley and Shure 1980). Soil parameters, such as soil depth, texture, strength, and chemistry, affect rodent burrowing and digging activities (Hardy 1945; Feldhamer 1979; Kitchings and Levy 1981).

Water availability also affects rodent distributions by altering the suitability of certain microhabitats, allowing greater overlap of competing species and influencing reproductive success (Christian 1979, 1980). Often these factors are ignored or underestimated in rodent ecological studies.

7.3.2 Program Summary

7.3.2.1 Rodent Distribution and Vegetal and Soil Characteristics

A. Rodent Distribution Of the 11 species studied, four rodents, western harvest mouse, pinyon mouse, desert woodrat, and bushy-tailed woodrat, do not burrow in the soil. The canyon mouse and deer mouse use both above-ground and below-ground nest sites. The remainder, the least chipmunk, white-tailed antelope squirrel, Apache pocket mouse, Ord's kangaroo rat, and montane vole are dependent on underground burrows. Most of the rodents demonstrated a density preference for one of the four vegetation types over a nine-year period.

B. Vegetal Characteristics Most of the rodents except the bushy-tailed woodrat, demonstrated a significant preference or avoidance of some vegetal characteristic among and within the four vegetation types. In some cases, these preferences agreed with published information; in other cases a higher resolution, as documented in this study, is necessary to determine rodent distribution.

C. Soil Characteristics Soils did not play as major a role in rodent distribution as anticipated. Nevertheless, soil's role in indicating the distribution of two rodents with the most stable populations, Apache pocket mice and Ord's kangaroo rats, is clearly evident from analysis.

7.3.3 Program Description

7.3.3.1 Objectives Three major objectives of the rodent distribution study are: (1) describe microhabitat features of four vegetation types at Ua-Ub; (2) determine significant relationships between rodents and vegetal and soil characteristics for monitoring and impact detection; and, (3) provide

guidelines for reestablishing and predicting rodent populations on disturbed areas and disposed oil shale. Three criteria were used to meet these objectives:

- o Review natural history and habitat preferences, both vegetal and soil, for rodents at Ua-Ub.
- o Analyze rodent habitat preference using density in vegetation types over a nine-year period.
- o Evaluate selected vegetal and soil characteristics for their effects on rodent distribution.

7.3.3.2 Methods To ascertain which factors influenced rodent habitat selection, the vegetation and soils of each trapping grid were surveyed and mapped during the summer of 1983. Detailed descriptions of the vegetation and soils are contained in Appendices A and B, respectively.

A. Rodent Sampling Detailed descriptions of rodent trapping methodology and locations were presented in the Environmental Monitoring Manual (WRSOC 1982). Data used for this analysis were initial capture location of individual rodents within four major trapping grids sampled in August from 1975 through 1981 (Grids WG-1, WS-1, WJ-1, WR-1). From 1981 through 1983 five more grids were trapped (Grids WG-2, WG-3, WS-4, WJ-5, WR-2); and in 1982 and 1983 grid WR-4 replaced grid WR-1, increasing the database. Rodent densities were calculated and analyzed by vegetation type and year (two-way ANOVA with no replicates, mean comparison using Least Significance Difference, Steel and Torrie 1960) using grids WG-1, WS-1, WJ-1, WR-1, and WR-4.

B. Vegetation Sampling Annual plant sampling occurred during June 1983. Samples were collected from 30 0.25 m^2 (0.5 x 0.5 m) quadrats randomly placed throughout each rodent grid. Percent cover of annual plants, perennial plants, litter, rock, and mean annual plant height were measured at each sampling point.

Perennial plants were sampled during October 1983. Data were collected from 30 1.0 m^2 (1.0 x 1.0 m) quadrats randomly placed throughout each rodent trapping grid. Percent total plant cover, annual and perennial plant cover, rock, litter, and bare ground were measured. To rank the dominant perennial plants of each grid, importance values were calculated by summing a species' realtive cover, relative frequency, and relative density. Important values range from 1 to 300.

The vegetation of each rodent trapping grid was mapped using low-level aerial photography and ground-truthed. A characteristic map unit (hereafter referred to as vegetal group) was named according to the dominant plant species. Thus, a vegetal group is a sub-unit within a vegetation type. Within each vegetal group, percent total plant cover, vegetal structure (the number of plant layers occurring in the vegetal group), and canopy height were measured. These parameters, along with vegetation type and vegetal group, were used to evaluate the influence of vegetation on rodent distribution.

C. Soil Description Soils were described by an Order 1 soil survey of the 10 rodent trapping grids. The field investigation was initiated in the spring of 1983. Initially, landscape units were delineated on low altitude aerial photographs. Landscape units were further divided into topographic

positions with distinctive slope, aspect, and microtopography. A soil pit was excavated to a depth of 150 cm or to lithic contact, if shallower than 150 cm, for each representative topographical position within each grid. Twenty-eight soil profiles were described.

Soils were classified to the family taxonomic level according to Soil Conservation Service criteria. Soil taxa were verified and/or amended by additional investigation. Auger borings along grid lines were used to verify map unit boundaries to determine composition and to estimate percent area of inclusions in map unit delineations.

Interpretations were conducted for typic pedons of each soil type. Interpretations included those properties thought to influence the distribution of rodent populations:

- o Depth of soil.
- o Coarse-fragment composition.
- o Consistence of soil material.
- o Drainage.
- o Run-on water from contiguous positions.
- o Position relative to erosion adn/or deposition and flooding.
- o Slope and aspect.

D. Data Analysis Initial capture locations for each rodent species were analyzed separately using a Chi-square goodness of fit test (Zar 1974) to compare the number of captures within each vegetal group or soil type with the number expected if the captures occurred at random with respect to mapped attributes at trapping stations. Several considerations influenced the cal-

culation of the expected distribution of captures. The capture data were envisioned as the results of a series of "preference tests" conducted at ten locations. The random hypothesis assumed that a rodent captured on a grid could have been captured with equal probability at any of the 144 trapping stations on that grid if its selection of area to inhabit was not influenced by the mapped soil or vegetal characteristics. Since the trapping grids are remotely located, it was also assumed that an individual rodent had zero probability of being captured at a trap station on another grid. Therefore, calculation of expected numbers of captures in each vegetal group or soil type was performed on a grid-by-grid basis and pooled over all grids for calculation of a single Chi-square statistic.

Consequences of this method of analysis should be noted. Some species of rodents were completely absent from some grids (usually all of the grids of some large scale vegetation type). This resulted in the expected numbers under the random hypothesis to be zero for those grids and completely eliminated some vegetal groups or soil types from the analysis for those rodent species. Non-random distributions at this large scale have already been documented. This analysis was designed to ignore the large scale non-randomness which would otherwise have made it impossible to detect (with a Chi-square analysis) non-randomness at the higher resolution smaller scale of interest.

Some trapping stations were located near boundaries between two mapped categories. Since trap placement varied somewhat from year to year and edge effects from nearby mapped units were not known, trap stations nominally located within three meters of a mapped boundary were classified as "edge",

regardless of vegetal or soil component classifications, and were included in the calculation of expected numbers but were excluded from calculation of the total Chi-square statistic.

7.3.4 Program Results and Analysis

7.3.4.1 Rodent Interactions with Vegetation and Soils Distribution of 11 rodent species were analyzed according to vegetal characteristics listed in Table 7.3-1 and according to soil characteristics listed in Table 7.3-2. Additional information on vegetal, soil, and seed characteristics of each grid are found in Section 5.4.

7.3.4.2 Rodent Species

A. Least Chipmunk (Eutamias minimus) Least chipmunks occur throughout Canada to the north and in the United States from the western parts of the Dakotas and Colorado to the east, central Oregon and Washington to the north, eastern California to the west, central Arizona and New Mexico to the south, usually residing in sagebrush far from conifers or in sagebrush among conifers (Hall and Kelson 1959). In Colorado, least chipmunks are found in semi-arid greasewood to areas above timberline with a preference for more mesic and less rocky habitats than Colorado chipmunks (E. quadrivittatus). On the East Tavaputs Plateau which encompasses Ua-Ub, least chipmunks occurred from pinyon-juniper woodland to alpine savannah in the Roan Cliffs, preferring the latter, ranging in elevation from 5000-9000 ft (Ranck 1961). The Colorado chipmunk also occurs on the Plateau, rarely above 7000 ft, and prefers dry canyons with sandstone outcrops (Ranck 1961). This author also noted that where the two species overlapped the Colorado chipmunk was dominant.

Table 7.3-1. Percent of occurrence, plant cover, canopy height, and vegetal structure for the vegetation groups at each rodent trapping grid at Ua-Ub.

Vegetation Type	Rodent Grid	Vegetal Group	% of Grid	% Plant cover	Canopy Height, m	Vegetal Structure
Greasewood	WG-1	Big Sagebrush-Greasewood	70	40	1.3	2-layered
		Greasewood-Cheatgrass	13	75	1.3	2-layered
		Rubber Rabbitbrush	1	35	1.0	1-layered
		Black Sagebrush	9	25	0.4	2-layered
		Cheatgrass	6	80	0.4	1-layered
		Wash	2	-	-	-
	WG-2	Big Sagebrush-Greasewood	71	25	1.0	2-layered
		Black Sagebrush	27	20	0.3	2-layered
		Wash	2	-	-	-
	WG-3	Big Sagebrush-Greasewood	38	50	0.8	2-layered
		Big Sagebrush-Greasewood(tall)	20	55	1.5	2-layered
		Big Sagebrush	1	40	0.5	1-layered
		Cheatgrass	36	80	0.6	1-layered
		Low Rabbitbrush-Cheatgrass	3	25	0.3	1-layered
		Rock	1	10	0.2	1-layered
		Wash	1	-	-	-
Shadscale	WS-1	Shadscale	49	50	0.4	2-layered
		Big Sagebrush	15	50	0.5	1-layered
		Shadscale-Big Sagebrush	8	50	0.5	2-layered
		Cottonthorn Horsebrush-Cheatgrass	18	25	0.5	2-layered
		Big Sagebrush-Shadscale	9	60	0.5	2-layered
		Bull Thistle	6	10	0.2	1-layered
	WS-4	Big Sagebrush-Shadscale	65	25	0.5	2-layered
		Shadscale-Big Sagebrush	13	25	0.4	2-layered
		Utah Juniper-Big Sagebrush	13	15	3.0	3-layered
		Rock	9	5	0.1	1-layered

Table 7.3-1. (contd.)

Vegetation Type	Rodent Grid	Vegetal Group	% of Grid	% Plant cover	Canopy Height, m	Vegetal Structure
Juniper	WJ-1	Utah Juniper-Black sagebrush	68	20	3.0	3-layered
		Utah Juniper-Big Sagebrush	19	35	3.5	3-layered
		Big Sagebrush	6	35	0.7	1-layered
		Big Sagebrush-Cheatgrass	3	20	0.5	2-layered
		Greasewood-Low Rabbitbrush	4	30	0.6	2-layered
	WJ-5	Utah Juniper-Black Sagebrush	48	20	3.0	3-layered
		Utah Juniper-Big Sagebrush	26	30	4.0	3-layered
		Big Sagebrush	4	25	0.5	1-layered
		Black Sagebrush	21	20	0.3	1-layered
		Wash	1	-	-	-
Riparian	WR-1	Fremont Poplar	56	60	30.0	3-layered
		Rabbitbrush-Western Wheatgrass	23	70	1.0	2-layered
		Fivestamen Tamarisk	21	60	3.0	2-layered
	WR-2	Fremont Poplar	38	70	25.0	3-layered
		Rabbitbrush-Western Wheatgrass	34	50	0.7	2-layered
		Rubber Rabbitbrush-Greasewood	8	50	1.5	2-layered
		Fivestamen Tamarisk	12	45	2.0	2-layered
		Spreading Rabbitbrush	5	80	1.3	1-layered
		Western Wheatgrass-Kentucky Bluegrass	3	50	0.3	1-layered
	WR-4	Fremont Poplar	51	60	25.0	3-layered
		Rabbitbrush-Western Wheatgrass	41	60	0.8	2-layered
		Fivestamen Tamarisk	8	50	2.0	2-layered

Table 7.3-2 Percent occurrence, geographic position, soil depth and soil rockiness of the soil groups for each rodent trapping grid at Ua-Ub.

Vegetation Type	Rodent Grid	Soil Group	% of Grid	Geographic Position	Soil Depth	Rocky?
Greasewood	WG-1	32a	20	Alluvium	Deep	no
		11kbc	12	Residuum	Shallow	yes
		33ab	68	Alluvium	Deep	no
	WG-2	33ab	40	Alluvium	Deep	no
		11kbc	32	Residuum	Shallow	yes
		22kbc	28	Alluvium	Deep	yes
	WG-3	11kbc	5	Residuum	Shallow	yes
		31a	52	Alluvium	Deep	no
		22kbc	40	Alluvium	Deep	yes
		w	3	Alluvium	Deep	no
Shadscale	WS-1	12kd	13	Residuum	Shallow	yes
		21bc	47	Residuum	Moderate	yes
		22b	33	Alluvium	Deep	yes
		R	9	Residuum	Shallow	yes
	WS-4	11kbc	15	Residuum	Shallow	yes
		31a	1	Residuum	Moderate	no
		41a	13	Residuum	Moderate	no
		51a	58	Residuum	Moderate	no
		R	13	Residuum	Shallow	yes
Juniper	WJ-1	11kbc	56	Residuum	Shallow	yes
		14xc	16	Residuum	Shallow	yes
		22kbc	28	Alluvium	Deep	yes
	WJ-5	11kbc	29	Residuum	Shallow	yes
		13xde	51	Residuum	Shallow	yes
		22kbc	20	Alluvium	Deep	yes

Table 7.3-2 (contd.)

Vegetation Type	Rodent Grid	Soil Group	% of Grid	Geographic Position	Soil Depth	Rocky?
Riparian	WR-1	63a'	76	Fluvent(upper)[1]	Deep	no
		72a	16	Fluvent(lower)	Deep	no
		72a'	8	Fluvent(lower)	Deep	no
	WR-2	61a	40	Fluvent(upper)	Deep	no
		62a	35	Fluvent(upper)	Deep	no
		62a'	8	Fluvent(upper)	Deep	no
		72a	17	Fluvent(lower)	Deep	no
	WR-4	62a	86	Fluvent(upper)	Deep	no
		63a	8	Fluvent(upper)	Deep	no
		71a	6	Fluvent(lower)	Deep	no

[1]Bench position

At Ua-Ub, the habitats where chipmunks were plentiful favored the presence of the Colorado chipmunk. Based on measurements of length of body, tail, hindfoot, and ear, plus weight, the chipmunks at Ua-Ub are E. minimus. Ranck (1961) and Durrant (1952) claimed the subspecies was E.m. operarius; however, Armstrong (1972) suggested it was E.m. consobrinus. Data from Ua-Ub support the presence of the former subspecies based mainly on weights published by the latter author.

The least chipmunk occurred at highest density in juniper vegetation (1.4±1.4 ind/ha) compared to greasewood (0.1±0.2 ind/ha) and riparian (0.09±0.27 ind/ha) ($p \leq 0.95$). One chipmunk was captured at shadscale site WS-4 in 1982, and none were seen or captured at WS-1 through nine years. Among the vegetation types, the chipmunk distinctly favored plant cover of less than 25 percent and avoided cover between 25-50 percent ($p \leq 0.995$). For vegetal structure and canopy height, there were high expected and observed values for three-layered vegetation and canopy height exceeding 1.5 m. Between a single- and double-layered structure, least chipmunks favored the former and avoided the latter ($p \leq 0.995$). Between the low (<0.5 m) and median (0.5-1.5 m) canopies, the former again was favored and the latter avoided ($p \leq 0.999$). Within juniper vegetation, the chipmunk favored the low cover (<25%) and avoided the median cover (25-50%) ($p \leq 0.99$). Although the relationships were not significant, Utah juniper-black sagebrush was the most frequented area in juniper vegetation.

In terms of soils among all sites, shallow soils were preferred, deep soils avoided ($p \leq 0.975$); residual soils were favored over alluvial soils ($p \leq 0.975$), and non-rocky soils were definitely avoided ($p \leq 0.95$).

B. White-tailed Antelope Squirrel (Ammospermophilus leucurus) The white-tailed antelope squirrel is a diurnally-active rodent residing in desert shrub vegetation at low elevations and extending into adjacent pinyon-juniper woodlands throughout the Great Basin and the Colorado River Basin Deserts (Hall and Kelson 1959). In New Mexico the squirrel occurred mainly in grasslands and marginal pinyon-juniper rather than desert shrub and avoided riparian vegetation along floodplains (Findley et al. 1975). On the East Tavaputs Plateau, which encompasses Ua-Ub, the squirrel did not occur above 6250 ft and was more common in lower elevation desert shrub habitats than in higher elevation juniper and pinyon-juniper woodlands (Ranck 1961).

At Ua-Ub, the squirrel's density was higher in desert shrub habitats of greasewood (1.5±2.2 ind/ha) and shadscale (1.2±1.9 ind/ha) compared to juniper (0.4±0.5 ind/ha). The squirrel avoided riparian vegetation along the White River but did occur in Evacuation Creek's mixture of tamarisk, rabbitbrush, and greasewood. Among all vegetation types at Ua-Ub, the squirrel demonstrated a distinct preference for plant cover of less than 25 percent and a distinct avoidance of plant cover of more than 50 percent ($p \leq 0.95$). Within greasewood vegetation type, the squirrel preferred low rabbitbrush-cheatgrass ($p \leq 0.999$).

The most often-cited soil types where the squirrel occurred were rock outcrops, river-sorted boulder fields, and sandy, stony, rocky, or gravelly soils (Durrant 1952; Ingles 1965; Armstrong 1972; Findley et al. 1975). At Ua-Ub, no distinct preference for soils was found among all grids. Within the greasewood vegetation type, there were preferences for shallow soils ($p \leq 0.975$), for rocky soils ($p \leq 0.995$), and for soil type 11Kbc, with an

avoidance of soil type 31a ($p \leq 0.999$).

The squirrel's preference for soil types agreed in most part with published accounts. Had the drought not radically reduced the squirrel's population for seven years (1977-1983) compared to 1975-1976 ($p \leq 0.99$), Ranck's (1961) conclusion that desert shrub supported a higher density than pinyon-juniper woodlands would appear correct. The observation by Findley et al. (1975) of a grassland preference and the squirrel's actual preference for low plant cover and rabbitbrush-cheatgrass at Ua-Ub suggests that such a broad habitat preference as desert shrub is misleading. At Ua-Ub the preference is rocky soils with low plant cover and grasses present.

C. Apache Pocket Mouse (Perognathus apache) The Apache pocket mouse is a nocturnally-active rodent that digs its own burrows and resides in dry, open plains and deserts covered by desert shrub and juniper woodlands in eastern Utah, western Colorado, northeastern Arizona, and northwestern to central and southern New Mexico (Hall and Kelson 1959). However, Findley et al. (1975) reclassified P. apache as P. flavescens in New Mexico. This small pocket mouse prefers sandy soils and burrows beneath cactus and low shrubs in Colorado (Armstrong 1972). On the East Tavaputs Plateau, the pocket mouse overlaps another heteromyid rodent, Ord's kangaroo rat (Dipodomys ordii) and is less abundant than the latter due, possibly, to the pocket mouse's solitary nature and the kangaroo rat's gregarious nature, hence an underestimation of the mouse's population (Ranck 1961).

At Ua-Ub the pocket mouse occurred at higher densities in greasewood (2.9 ± 2.3 ind/ha) and shadscale (2.7 ± 1.4 ind/ha) vegetation types than in juniper (1.4 ± 0.9 ind/ha) and riparian (0.3 ± 0.6 ind/ha) vegetation ($p \leq 0.95$).

Among all vegetation types, the pocket mice preferred a plant cover of 25-50 percent and avoided areas with less than 25 percent ($p \leq 0.999$), preferred two-layered vegetal structure, avoided three-layered areas ($p \leq 0.99$), and avoided canopy height greater than 1.5 m ($p \leq 0.99$).

In greasewood vegetation, the pocket mouse showed a slight preference for the cheatgrass group, a distinct preference for the big sagebrush group, and an avoidance of tall big sagebrush-greasewood group ($p \leq 0.99$). In shadscale and juniper vegetation types, it preferred plant cover of 25-50 percent and avoided cover of less than 25 percent ($p \leq 0.975$ and 0.99, respectively). In shadscale one-layered vegetal structure was avoided and two-layers preferred ($p \leq 0.975$), whereas in juniper one-layer was preferred and three-layers avoided ($p \leq 0.999$). The canopy height provided by shrub vegetation (0.5-1.5 m) was also preferred in juniper and the juniper trees avoided ($p \leq 0.999$). The preferred vegetal groups in shadscale were shadscale, shadscale-big sagebrush,and spiny horsebrush-cheatgrass groups ($p \leq 0.999$). However, in juniper the big sagebrush group was preferred and the juniper-black sagebrush group avoided ($p \leq 0.999$).

The concensus of published accounts showed that Apache pocket mice prefer sandy soils. At Ua-Ub the mice distinctly avoided shallow soils with a preference for moderately deep soils ($p \leq 0.999$). This same pattern was present in shadscale soils ($p \leq 0.975$) with a preference for 21bc soils and an avoidance of 12Kd soils ($p \leq 0.975$). In juniper moderately deep soils were heavily preferred and shallow soils avoided ($p \leq 0.999$); hence, alluvial soils were favored over residual soils ($p \leq 0.999$) and non-rocky soils distinctly preferred ($p \leq 0.999$). 11Kbc soil type was definitely avoided and 32a type

definitely favored ($p \leq 0.999$). Sandy soils were not an important factor at Ua-Ub, rather the depth and slope appeared to dictate the pocket mouse's residence. Overall, vegetation characteristics appeared to be more indicative of this small rodent's distribution when compared to soils except in juniper vegetation where soils were limiting.

D. Ord's Kangaroo Rat (Dipodomys ordii) Ord's kangaroo rats are nocturnal rodents residing in semi-arid to arid climates at low elevations, preferring an area with proper drainage and any combinatin of soil and climatic factors that provide an abundance of seed plants and light ground cover, ranging from Kansas and Nebraska to the east, southern Canada and central Washington to the north, eastern California to the west, and central Mexico to the south (Hall and Kelson 1959). In Colorado sandy soils of sandbars and sandy banks of ephemeral streams at low elevations are optimal conditions for the kangaroo rat (Armstrong 1972). Findley et al. (1975) for New Mexico, Ingles (1965) for the Pacific states, and Ranck (1961) for the East Tavaputs Plateau all agree that sandy soils and marked aridity are the keys to kangaroo rat distribution.

At Ua-Ub greasewood vegetation supported the highest density of kangaroo rats (8.0 ± 5.5 ind/ha) compared to the other three types, and shadscale vegetation supported a higher density (3.5 ± 2.4 ind/ha) than juniper (0.2 ± 0.4 ind/ha) and riparian (0.2 ± 0.3 ind/ha) vegetation types ($p \leq 0.95$). Among all vegetation types, kangaroo rats distinctly avoided plant cover of less than 25 percent with a slight preference for 25-50 percent cover ($p \leq 0.999$). They distinctly avoided three-layered vegetal structure with a preference for two layers ($p \leq 0.999$) and avoided a canopy height of less than 0.5 m with a slight

preference for 0.5-1.5 m ($p \leq 0.99$).

In greasewood vegetation, cover of less than 25 percent was avoided with a preference for 25-50 percent cover ($p \leq 0.999$). A two-layered structure was preferred and one-layered structure avoided ($p \leq 0.975$). A canopy height greater than 1.5 m was distinctly preferred and less than 0.5 m avoided ($p \leq 0.999$); and the favored vegetal groups were tall big sagebrush-greasewood, big sagebrush, and big sagebrush-greasewood with a definite avoidance of black sagebrush ($p \leq 0.95$). However, in shadscale vegetation, the kangaroo rats definitely avoided the big sagebrush group as well as bull thistle and showed a slight preference for spiny horsebrush-cheatgrass ($p \leq 0.95$).

Since kangaroo rats invaded the juniper and riparian vegetation types in 1980 and 1981 when densities reached record highs in greasewood and shadscale ($p \leq 0.95$), the information for the wooded types is sketchy. However, in riparian vegetation the kangaroo rats avoided cottonwood and tamarisk groups and showed a very high preference for the rubber rabbitbrush-greasewood group ($p \leq 0.999$). It is possible that this vegetal group was present in the ephemeral streams as noted by Armstrong (1972). Notably, the location of this vegetal group along the White River occured in an area where upland flash floods deposited sandy soils on the riparian vegetation's periphery.

Among the soils at Ua-Ub, kangaroo rats avoided shallow soils and preferred deep soils ($p \leq 0.999$), preferring alluvial soils and avoiding residual soils ($p \leq 0.999$). Rocky soils were avoided and non-rocky soils preferred ($p \leq 0.975$). This same pattern was repeated for soils of greasewood vegetation with a preference for soil type 33ab and an avoidance of 11Kbc and 32a. The 33ab is more of a coarse, loamy soil, whereas 32a is a sandy, coarse, and

loamy soils. Deep soils were also preferred in shadscale vegetation ($p \leq 0.995$) as were alluvial soils ($p \leq 0.975$). Although a significance was not evident among soil types in shadscale, the deep 22Kbc soils on 3-15 percent slopes were avoided and 32a soils preferred. In riparian the 61a soil type associated with cottonwood was avoided with a decided preference for type 62a', a deep, eroded, sandy soil ($p \leq 0.999$).

Overall, both soils and vegetation played major roles in the kangaroo rat's distribution. The light ground cover mentioned by Hall and Kelson (1959), assuming this implied a plant cover of less than 25 percent, did not hold for Ua-Ub's populations nor was a preference for sandy soils consistent. In reference to Ranck's (1961) suggestion concerning underestimation of pocket mouse populations due to the kangaroo rat's gregariousness, the two seed-eating rodents did not consistently overlap in preferences for vegetation or soils, hence, the population estimates are likely correct.

E. Western Harvest Mouse (Reithrodontomys megalotis) The western harvest mouse is a nocturanl rodent occurring from western Illinois to the east, southern Canada to the north, the Pacific coast to the west, and southern Mexico to the south. It constructs globular nests of grass above ground in thick grasses, low shrubs, and, occasionally, trees and appears to thrive in areas disturbed by man, preferring thick stands of grass in more arid areas, especially grasses near water (Hall and Kelson 1959). In eastern Colorado, R. megalotis overlaps with R. montanus with the former found in rank vegetation in riparian-like habitats and the latter in more xeric grassy vegetation; whereas, in western Colorado, where R. montanus is absent, R. megalotis occurs in rough, xeric areas covered by sparse, dry grasses and Russian

thistle (Armstrong 1972). In Utah Durrant (1952) found western harvest mice to be extremely variable, showing a tendency for localized populations. On the East Tavaputs Plateau, Ranck (1961) found these mice in a variety of habitats ranging from sparse stands of cheatgrass to shadscale to mesic streamside habitats, never abundant but concentrated in grassy streamside situations.

At Ua-Ub western harvest mice occured sporadically in all vegetation types but at highest density in riparian (1.5 ± 1.8 ind/ha) ($p\leq0.95$). There were no decided preferences for any vegetal or soil characteristics among all sites except a preference for three-layered vegetation and an avoidance of two-layered vegetation in riparian areas and a preference for 61a and 71a soils in riparian areas. Our findings agreed with Ranck (1961) and suggested that the harvest mouse retains its preference for riparian-like habitats in western Colorado, though it did occur in more xeric habitats. Durrant's (1952) point of extreme variability is also supported by annual changes in harvest mouse density. In 1976 harvest mice peaked along with other cricetid rodents; peaked again in 1980 along with heteromyid rodents and again in 1983 along with the expansion of microtine rodents in riparian vegetation, all significant increases ($p\leq0.95$). Overall, neither vegetation nor soil characteristics played a major role in harvest mouse distribution, rather the more general character of vegetation type was dominant.

F. Canyon Mouse (Peromyscus crinitus) Canyon mice are highly discontinuous in distribution, being confined to rocky habitats from western Kansas to the east, central Oregon to the north, eastern California to the west, and northern Arizona and northwestern New Mexico to the south (Hall and Kelson

1959). On the East Tavaputs Plateau, canyon mice occurred at low abundance and were extremely localized in rocky habitats associated with pinyon-juniper woodlands (Ranck 1961), a situation also noted by Findley et al (1975) in New Mexico with burrows under rock escarpments or large boulders.

At Ua-Ub canyon mice occurred at low densities in juniper vegetation (1.1±1.0 ind/ha) with sporadic occurrence in rocky areas of shadscale vegetation which abuts the juniper vegetation type. Within juniper, canyon mice preferred one-layered vegetal structure ($p \leq 0.999$), a canopy height of 0.5-1.5 m ($p \leq 0.999$), and the big sagebrush group while avoiding Utah juniper-big sagebrush ($p \leq 0.999$). Preference for soil characteristics were not significant although expected values favored shallow and residual soils that were rocky. Overall, rocky habitats in association with one-layered big sagebrush within juniper woodlands appear to best define canyon mouse distribution.

G. Deer Mouse (Peromyscus maniculatus) Deer mice occur throughout north America from low elevation deserts to high elevation tundra (Hall and Kelson 1959). Ranck (1961) noted that deer mice were ubiquitous on the East Tavaputs Plateau, were most numerous at higher elevation mesic conditions (dense understory in aspen) but were few where they overlapped at higher elevations with long-tailed voles (Microtus longicaudus) and at lower elevations with Ord's kangaroo rats.

At Ua-Ub deer mice nested above ground as well as below ground and were the most abundant rodent, occurring at highest density in riparian vegetation (13.2±8.2 ind/ha) compared to greasewood (5.8±6.0 inc/ha), shadscale (5.8±6.5 ind/ha), and juniper (4.1 ±2.7 ind/ha) ($p \leq 0.999$). Among all vegetation types, deer mice definitely preferred areas with a plant cover of less than

25 percent ($p \leq 0.999$) and one-layered vegetal structure ($p \leq 0.999$). However, preference and avoidance within vegetation types suggested that deer mice adapt readily to different conditions.

In terms of plant cover, the deer mouse preferred less than 25 percent in both greasewood and shadscale vegetation ($p \leq 0.975$ and 0.999, respectively), in juniper preferred the low cover but definitely avoided 25-50 percent cover ($p \leq 0.999$), and in riparian where low cover was absent occurred as expected in both medium and dense areas. Vegetal structure did not play a role in greasewood but in shadscale and riparian types, one-layer was definitely preferred ($p \leq 0.999$ and 0.99, respectively), whereas two layers were avoided in juniper ($p \leq 0.95$). Canopy height played no role in riparian vegetation, but in greasewood a height of >1.5 m was preferred ($p \leq 0.995$), whereas 0.5-1.5 m was preferred in shadscale ($p \leq 0.975$), and <0.5 m was preferred and 0.5-1.5m avoided in juniper ($p \leq 0.999$).

Vegetal groups preferred in greasewood vegetation were black sagebrush and tall big sagebrush-greasewood, while greasewood-cheatgrass was avoided ($p \leq 0.999$). In shadscale big sagebrush, bull thistle, and spiny horsebrush-cheatgrass were preferred groups, and shadscale and rock were avoided ($p \leq 0.999$). In juniper black sagebrush was also preferred as was Utah juniper-black sagebrush, whereas big sagebrush, juniper-big sagebrush, and greasewood -low rabbitbrush were avoided ($p \leq 0.99$). In riparian deer mice occurred as expected in most groups but showed a definite preference for spreading rabbitbrush ($p \leq 0.999$).

Distribution among soils was not so complex, although the upland vegetation types seemingly skewed the relationships. Among all soils, the mice

preferred shallow soils with a slight avoidance of deep soils ($p \leq 0.95$) and a preference for residual soils and avoidance of alluvial soils occurring as expected in fluvial soils ($p \leq 0.99$). Distribution within soils in greasewood and juniper occurred as expected. In shadscale shallow soils were definitely favored and deep soils definitely avoided ($p \leq 0.999$), hence, a preference for residuum and avoidance of alluvium ($p \leq 0.995$), and a preference for 12Kd and slight avoidance of 11Kbc, which is shallow, and distinct avoidance of 22b, which is deep ($p \leq 0.999$). In riparian soils the lower bench area was preferred ($p \leq 0.95$) and soil type 71a was definitely preferred with slight preferences for 62a and 62a', while 61a and 72a were avoided ($p \leq 0.999$).

In summary, the rather paradoxical relationships among and within soil and vegetation characteristics is, perhaps, the best indicator of the deer mouse's widespread distribution and high abundance. In reference to Ranck's (1961) finding of high density in high elevation mesic habitats, low elevation mesic habitats (riparian cottonwoods) played a similar role. Notably over a nine-year period, the least variable population occurred in wooded vegetation types. Ranck's (1961) note that deer mice were at low density in the presence of kangaroo rats was the case in greasewood vegetation when density in the 1977 drought went to one mouse per ha and did not exceed 6 mice per ha through 1983. In 1975 and 1976, however, deer mouse densities were 9 and 21 ind/ha, respectively. In shadscale vegetation deer mice went to extinction in 1977, but the population recovered and has equalled or exceeded a 1975 density of 5 mice per ha through 1983. It appears that factors other than the presence of kangaroo rats influenced deer mouse population dynamics.

Overall, vegetation appears to play a more important role than soils in this mouse's distribution and abundance.

H. Pinyon Mouse (Peromyscus truei) Pinyon mice reside in pinyon-juniper woodlands from eastern Colorado and New Mexico to the east, central Oregon to the north, northern Nevada and Utah to the west, and Mexico to the south (Hall and Kelson 1959). In Colorado the pinyon mouse is the most arboreal of the Peromyscus genus, mostly confined to pinyon-juniper with nests constructed almost exclusively in the hollow branches of juniper trees (Armstrong 1972). On the East Tavaputs Plateau these mice occurred most frequently in rocky outcroppings in pinyon-juniper but were also found in mixtures of tamarisk and cheatgrass in Evacuation Creek and willow, clover, and rose in Bitter Creek (Ranck 1961).

At Ua-Ub pinyon mice occurred mainly in juniper vegetation (1.6 ± 1.9 ind/ha) compared to greasewood (0.1 ± 0.2 ind/ha) and riparian (0.04 ± 0.13 ind/ha) ($p\leq0.95$). In juniper vegetation this mouse preferred a canopy height of 0.5-1.5 m and avoided vegetation <0.5 m tall ($p\leq0.99$), the opposite of the canyon mouse. Although relationships were not significant among vegetal groups in juniper, the mouse showed an avoidance of black sagebrush, favored by the deer mouse, and a preference for big sagebrush, favored by the canyon mouse. No relationships with soils were significant with the mouse expected to occur on shallow but occasionally deep soils, in residual, and occasional alluvial soils, and in rocky soils. Occurrence of pinyon mice in greasewood was coincident with high densities in juniper. Its presence in riparian occurred in 1981 exclusively.

I. Desert Woodrat (Neotoma lepida) Desert woodrats, mainly nocturnal, usually prefer rocky places, building their houses at the base of cactii, shrubs, in rock crevices, or clay banks, and occur from western Colorado to the east, central Oregon to the north, Nevada and southern California to the west, and Baja California to the south (Hall and Kelson 1959). In Colorado woodrats den under cover of rocks and in shrub and pinyon-juniper woodland below 6200 ft (Armstrong 1972). On the East Tavaputs Plateau the woodrat occurs from 4000-6000 ft in all habitats with rocks present (Ranck 1961).

At Ua-Ub desert woodrats were at highest density in juniper vegetation (3.0 ± 2.5 ind/ha), the rockiest area, compared to greasewood (0.4 ± 0.6 ind/ha), shadscale (0.2 ± 0.6 ind/ha), and riparian (0.2 ± 0.3 ind/ha) ($p\leq0.99$). Among all vegetation types, the woodrats favored a plant cover of less than 25 percent and avoided areas covered with 25-50 percent and >50 percent ($p\leq 0.995$). They also avoided two-layered vegetal structure with a slight preference for three-layered structure ($p\leq0.975$). Although no significant relationships were found between vegetation and woodrats in juniper, these large rodents had a high expected and observed value for Utah juniper-black sagebrush, a three-layered, low-cover area.

Some significant relationships occurred in greasewood and shadscale vegetation types. These relationships need to be considered the woodrat's response to suboptimal habitat, since nine years of trapping clearly demonstrated that extinction of populations was more common than maintenance in these types. In greasewood woodrats preferred less than 25 percent cover and avoided any area with a greater than 25 percent cover ($p\leq0.999$) and avoided two-layered structure ($p\leq0.975$). In shadscale three-layered structure was

preferred ($p \leq 0.975$), a low canopy (<0.5 m) was avoided, and high canopy (>1.5 m) favored ($p \leq 0.999$). Vegetal groups preferred in shadscale were Utah juniper-big sagebrush and to a lesser degree spiny horsebrush-cheatgrass, while avoiding shadscale ($p \leq 0.975$).

In terms of soils, no overall relationship was evident with woodrats, but in suboptimal greasewood vegetation, shallow soils were favored, deep soils avoided ($p \leq 0.999$); hence, residual soils were favored and alluvial soils avoided ($p \leq 0.999$). Favored soil group was 11Kbc, with 22Kbc, 31a, and 32a avoided.

Overall, the desert woodrat responds to vegetal characteristics, primarily the presence of juniper, and to rocky situations which the juniper habitat provided in copious amounts.

J. Bushy-tailed Woodrat (Neotoma cinerea) Bushy-tailed woodrats occur as far east and north as the Dakotas, west to the Pacific coast from Washington to northern California, south to northern Arizona and northwestern New Mexico (Hall and Kelson 1959). In Colorado this large rodent occurs from desert to timberline with dens in vertical rock cracks, crevices, and chimneys, also using caves, tunnels, and rock shelves in preference to ground level dens (Armstrong 1972). On the East Tavaputs Plateau, the woodrat occurs from denuded sandstone deserts through pinyon-juniper woodlands to rocky talus at high elevations on the Roan Cliffs, usually in association with rock and strewn boulders (Ranck 1961).

At Ua-Ub bushy-tailed woodrats occurred at equivalent densities in both juniper (0.8 ± 1.0 ind/ha) and riparian (1.0 ± 1.0 ind/ha) vegetation. Through nine years, no woodrats were captured in major greasewood (WG-1) or shadscale

(WS-1) trapping sites, although a few were captured at WG-2 and WS-4 from 1981-1983. This woodrat's occurrence in riparian habitat with its absence of rock was initially surprising until individuals were followed into nest sites in cottonwood snags, usually occupying an abandoned woodpecker hole.

There were no relationships of woodrats to vegetal and soil characteristics, there were none. Nevertheless, when a woodrat was captured in juniper, greasewood, or shadscale, the capture location was near a rock escarpment or large boulder.

K. Montane Vole (Microtus montanus) Montane voles occur in eastern Colorado to the east, British Columbia to the north,the mountainous areas of the Pacific states, and as far south as mountainous areas of eastern Arizona and western New Mexico (Hall and Kelson 1959). In an area encompassing Ua-Ub and extending into Colorado, montane voles are yet to be recorded. Ranck (1961) suggested that with intensive collecting in the montane areas (the Roan Cliffs) of the East Tavaputs Plateau, the species would likely be found. In Colorado montane voles occur in moist meadows; however, grassy sites removed from standing water are also occupied with a range in elevation from 6000 ft to timberline (Armstrong 1972).

At Ua-Ub one montane vole was captured at site WR-2 in 1981. By 1982 density increased to 21.7 ind/ha at WR-2, but no voles were captured or encountered anywhere else along the White River. By 1983 the voles had invaded all fluvial deposits along the river and were captured at 6.2 ind/ha at WR-4 and 13.2 ind/ha at WR-2. In the same year voles were observed south of the river at greasewood sampling site WG-2 during April and June, but none were captured in August. At the riparian sampling sites, the voles preferred

the tamarisk and spreading rabbitbrush groups and avoided the cottonwood and rubber rabbitbrush-greasewood groups ($p \leq 0.95$). In terms of soils, they favored the lower bench ($p \leq 0.95$), distinctly preferring soil types 72a with a slight preference for 71a and avoiding types 61a and 62a' ($p \leq 0.95$). For this species, the soils appeared to play the major role; however, the vole's occurrence in dry, upland areas suggests the presence of sufficient grasses may be more of a key than soils.

7.3.5 References

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APPENDIX A

A.1 VEGETATION

The purpose of Appendix A is to provide a detailed vegetal description of each rodent trapping grid. Map units are delineated for each trapping grid in Figures 5.4-1 to 5.4-4, Section 5.4. The report of the baseline vegetal study was of great help in the preparation of this document (White River Shale Project 1977). Plant taxonomy follows Plummer et al. (1977) and Welsh and Moore (1973).

A.1.1 Sagebrush-Greasewood Vegetation Type

The sagebrush-greasewood vegetation type (hereafter referred to as the greasewood vegetation type) is found mainly in the oil shale tract Ua at elevations between 4680 to 4860 m. It dominates Southam Canyon and Asphalt Wash. At lower elevations it is contiguous with the riparian vegetation type. Juniper vegetation type is adjacent to greasewood at higher elevations. In many locations, greasewood fingers into the juniper vegetation type along their ecotone. Three trapping grids, WG-1, WG-2, and WG-3 are located within this vegetation type.

The greasewood vegetation type is readily recognized by the presence of big sagebrush (see Table A.1.1-1 for botanical names) and greasewood. Associated shrubs include spiny hopsage, low and rubber rabbitbrush, cottonthorn horsebrush, black sagebrush, and broom snakeweed. The herbaceous understory is sparse because of livestock grazing. Existing bunchgrasses, bluebunch wheatgrass, bottlebrush squirreltail, Indian ricegrass, and needle-and-thread grass usually grow within the canopy of shrubs. Important perennial forbs are Utah sweetvetch, desert parsley, Fendler euphorbia, and Engelmann fleabane.

Cheatgrass is the dominant annual grass. Other annual plants are Douglas chaenactis, yellow spiderflower, blue mustard, pinnate and flexweed tansymus tards, gilia, prairie pepperweed and Russian thistle.

Many wash areas exist within the sagebrush-greasewood vegetation type. Washes are usually used for vehicular travel.

A.1.1.1 WG-1. The location of WG-1 is in Southam Canyon. The trapping grid is divided by two major washes; ant hills are common throughout the grid. Rubber rabbitbrush and low rabbitbrush outline the washes. The vegetation has been disturbed by livestock grazing and vehicular travel.

Big sagebrush and greasewood are the dominant shrubs (Table A.1.1-2). Other important shrubs are spiny hopsage, cottonthorn horsebrush, and rubber rabbitbrush. Black sagebrush occurs infrequently near the boundary of the grid. Cheatgrass is the dominant understory plant with a pure stand occurring in the northern corner of the grid. A paucity of perennial grasses and forbs exist in WG-1. Total plant cover is approximately 40 percent with perennial and annual plant cover being divided about equally (Table A.1.1-3). Six vegetal groups are found within WG-1:

A. Big Sagebrush-Greasewood Group. The big sagebrush-greasewood group is dominant and covers 70 percent of the grid. Big sagebrush and greasewood are the common shrubs. Plant cover is about 40 percent with a shrub canopy height of 1.0 to 1.25 m.

B. Greasewood-Cheatgrass Group. The greasewood-cheatgrass occupies approximately 13 percent and occurs mainly in the middle-upper portion of the grid. Greasewood is the dominant shrub and cheatgrass the dominant understory plant. Total plant cover is 75 percent. Greasewood plant height varies from

1.0 to 1.25 m, while cheatgrass height is 25 cm.

C. Cheatgrass Group. The cheatgrass group is located in the northwestern portion of WG-1 and occupies 6 percent of the grid. Plant cover is over 80 percent. Cheatgrass height varies from 30 to 40 cm.

D. Rubber Rabbitbrush Group. This group is located along the upper wash and occupies one percent of the grid. Rubber rabbitbrush is essentially the only species. Plant cover is about 35 percent, and the shrubs are 0.75-1.0 m tall.

E. Black Sagebrush Group. The black sagebrush group is an extension of the juniper vegetation type into the WG-1 trapping grid. It occurs in the northeast and southeast corners and occupies a small portion of the western boundary. The vegetal group occupies 9 percent of the WG-1. Black sagebrush is the dominant shrub. Juniper saplings, cheatgrass, broom snakeweed, and shadscale also occur. Plant cover is less than 25 percent. Plant height varies from 25 to 40 cm.

F. Wash Area. Two washes traverse the grid. One wash enters the grid from the southeast corner, while the other enters from the southwest corner. Both converge centrally at the grid's northern boundary. Rubber rabbitbrush grows along the periphery of the washes.

A.1.1.2 WG-2. The location of WG-2 is in the northwestern part of Southam Canyon. The trapping grid is dissected by two major washes with surface sheet erosion occurring in the northern portion of the grid. Rubber rabbitbrush is common along the periphery of the washes. The vegetation has been disturbed by livestock grazing and trampling.

The dominant shrubs are big and black sagebrush and greasewood (Table

B.1.1-2). Other important shrubs are cottonthorn horsebrush, broom snakeweed, and spiny hopsage. Perennial plant understory is sparse. However, cheatgrass cover is approximately 5 percent. Total plant cover is about 25 percent with perennials providing the majority of cover (Table A.1.1-3). Three vegetal groups are located wtihin WG-2:

A. Big Sagebrush-Greasewood Group. The big sagebrush-greasewood group occupies 71 percent of WG-2. Other shrubs are spiny hopsage, rubber rabbitbrush, and cottontop horsebrush. A few Indian ricegrass plants grow within the canopy of shrubs. Total plant cover is about 25 percent. Plant canopy height is about 1.0 m.

B. Black Sagebrush Group. The black sagebrush association is an extension of the juniper vegetation type into WG-2, and it occupies 27 percent of the grid. This group is restricted to small knolls within the grid. The dominant plant is black sagebrush. Other plants include low rabbitbrush, rock goldenrod, galleta grass, and bluebunch wheatgrass. Plant cover is less than 20 percent. Plant height varies from 10 to 30 cm.

C. Wash. One major wash exists in the northern portion of the trapping grid with several minor washes draining into it which extend over the trapping grid. Few plants grow within the washes. The wash area occupies 2 percent of WG-2.

A.1.1.3 WG-3. The location of WG-3 is in Asphalt Wash. The trapping grid is traversed by a dirt road which runs north and south. The vegetation of the rodent grid has been greatly altered by livestock grazing. Cheatgrass and Russian thistle plants are abundant.

Big sagebrush is the dominant shrub on the grid with two subspecies

present (Table A.1.1-2). Wyoming big sagebrush occurs on the drier portions of the grid while basin big sagebrush occurs along the wash and the eastern boundary. Rubber rabbitbrush, greasewood, and cottonthorn horsebrush are other shrubs within the grid. Total plant cover is about 60 percent with perennial plants providing 10 percent cover (Table A.1.1-3). Seven vegetal groups compose the big sagebrush-greasewood vegetation of WG-3:

A. Big Sagebrush-Greasewood Group. The dominant shrubs are Wyoming big sagebrush and greasewood. This group occurs on the western portion of the grid, and covers 38 percent. Individual shrubs are spaced far apart with thick stands of cheatgrass and Russian thistle plants growing in the interspaces. Other occasional shrubs include spiny hopsage, rubber rabbitbrush, and cottonthorn horsebrush. Ground cover is greater than 50 percent. Shrub height is approximately 80 cm, and cheatgrass height ranges from 20 to 50 cm.

B. Big Sagebrush-Greasewood (Tall) Group. Basin big sagebrush and large greasewood plants occur along Asphalt Wash and the eastern boundary. Other plants include cheatgrass and Torrey seepweed. Ground cover is approximately 55 percent. Shrub height varies from 0.5 to 1.5 m. This association occurs on 20 percent of the grid.

C. Big Sagebrush Group. The big sagebrush group occurs on 1 percent of WG-3 and is located near its southwestern corner. Wyoming big sagebrush is the only shrub present. Cheatgrass cover is less than 1 percent. Shrub cover and height are 40 percent and 0.4 m, respectively.

D. Cheatgrass Group. The cheatgrass group covers 36 percent of the grid. Cheatgrass is the dominant species and provides a dense ground cover of 75 percent. A few rubber rabbitbrush, greasewood, and Wyoming big sagebrush

plants are present. Russian thistle is interspersed among the cheatgrass. Cheatgrass height ranges from 30 to 60 cm.

E. Low Rabbitbrush-Cheatgrass Group. This group occupies 3 percent of WG-3 and is found growing on alluvial fans along its western boundary. Low rabbitbrush and cheatgrass are the important plants. Black sagebrush and broom snakeweed are also present. Plant cover is less than 25 percent. Plant height is approximately 30 cm.

F. Rock. A rock outcrop occurs in the southwest corner and occupies 1 percent of WG-3. Pockets of soil support shadscale, rock goldenrod, and broom snakeweed plants. Plant cover is less than 10 percent. Plant height ranges from 10 to 20 cm.

G. Wash. Asphalt wash runs north and south across WG-3 essentially in the middle of the grid. Rubber rabbitbrush, cheatgrass, and Russian thistle cover is sparse.

A.1.2. Juniper Vegetation Type. The juniper vegetation type is located mainly in the oil shale tract Ua and the southwestern portion of Ub above 4860 m in elevation. It extends southward from the sagebrush-greasewood vegetation type. Two rodent trapping grids, WJ-1 and WJ-5, are located in this vegetation type.

The juniper vegetation type is easily recognized by the presence of Utah juniper. Pinyon pine is an infrequent species on the oil shale tracts. Dominant shrubs are black sagebrush, big sagebrush, shadscale, broom snakeweed, low rabbitbrush, and slenderbush eriogonum. Herbaceous species include Indian ricegrass, galleta grass, bluebunch wheatgrass, Utah sweetvetch, Hoods phlox, and rock goldenrod. The common annual plants are cheatgrass, Douglas

chaenactis, erigonum, gilia, prairie pepperweed, annual stickweed, pinnate tansymustard, desert Indianwheat, and tumble mustard.

The juniper vegetation type has been overgrazed by livestock, thus herbaceous plants are sparse. Surface erosion has a high potential because of steep slopes, low understory plant cover, and shallow, rocky soils. The range condition of the juniper vegetation type is poor.

A.1.2.1 WJ-1

The WJ-1 rodent trapping grid is located in Southam Canyon. The vegetation can be readily categorized by the presence of black sagebrush or big sagebrush. Big sagebrush grows in the deep, well-drained soils of drainage areas. Black sagebrush occurs on shallow, rocky soils of ridge slopes. Two small ridges traverse the grid.

Utah juniper is the characteristic plant of this grid (Table A.1.1-2). Broom snakeweed, galleta grass, Indian ricegrass, Utah sweetvetch, and Fendler euphorbia compose the understory plants. Cheatgrass cover is not as extensive as in the other vegetation types. Total plant cover is about 25 percent (Table A.1.1-3). Five vegetal groups compose the vegetation of WJ-1:

A. Juniper-Black Sagebrush Group. This group occupies 68 percent and occurs on the ridge slopes within WJ-1. Utah juniper and black sagebrush are the dominant plants. Other plants include low rabbitbrush, Utah sweetvetch, rock goldenrod, Indian ricegrass, galleta grass, shadscale, and broom snakeweed. Plant cover is less than 20 percent. Juniper canopy height is 2 to 3 m with a plant understory height of less than 30 cm.

B. Utah Juniper-Big Sagebrush Group. Utah juniper and Wyoming big sagebrush characterize this association. The juniper-big sagebrush group

occupies 19 percent of WJ-1 and is located in the drainage areas between the ridge slopes. Other plants are similar to those in the juniper-black sagebrush association, except low rabbitbrush is replaced by rubber rabbitbrush. Plant cover varies from 30 to 35 percent. Utah juniper height is 3-4 m, and plant understory height is 20 to 50 cm.

C. Big Sagebrush Group. This minor group occupies 6 percent of the trapping grid and is located in the northeastern corner. Big sagebrush is the dominant shrub. Associated plants are cottonthorn horsebrush, greasewood, needle-and-thread grass, and cheatgrass. Plant cover is about 35 percent. Plant canopy height is 50-75 cm.

D. Big Sagebrush-Cheatgrass Group. This minor plant association is located in the southeastern corner on a rocky slope with a southern exposure. The big sagebrush-cheatgrass association occupies 3 percent of WJ-1. Shadscale, fringed sage, and Indian ricegrass are associated with cheatgrass and big sagebrush. Plant cover is 20 percent. Plant height varies from 20 to 50 cm.

E. Greasewood-Low Rabbitbrush Group. This minor vegetal group occupies 4 percent of WJ-1 and is located in the southeastern corner in a drainage. Big sagebrush is associated with greasewood and low rabbitbrush. A few clumps of cheatgrass are also present. Plant cover and canopy height are 30 percent and 60 cm, respectively.

A.1.2.2 WJ-5. The rodent trapping grid WJ-5 is located just southwest of the WRSP plant site. As with WJ-1, the vegetation can easily be divided based on black sagebrush or big sagebrush. Black sagebrush grows on the dry,

rocky slopes, while big sagebrush grows in drainage areas with deep, moist soils.

In addition to the sagebrushes, Utah juniper is characteristic of WJ-5 (Table A.1.1-2). Utah juniper is more common in the drainages than on the slopes. Other important plants are rubber rabbitbrush, slenderbush eriogonum, broom snakeweed, galleta grass, shadscale, low rabbitbrush, littleleaf brickellia, bluebunch wheatgrass, Indian ricegrass, and rock goldenrod. Total plant cover is approximately 21 percent. Cover for annual and perennial plants is 21 percent (Table A.1.1-3). Five vegetal groups comprise the vegetation of WJ-5:

A. Utah Juniper-Big Sagebrush Group. The Utah juniper-big sagebrush group is located in the drainages and occupies 48 percent of WJ-5. Other plants in the association include rubber rabbitbrush, Utah sweetvetch, greasewood, Indian ricegrass, broom snakeweed, and galleta grass. Plant cover ranges from 20 to 30 percent. Juniper trees vary in height from 2 to 4 m. Understory plant height is less than 70 cm.

B. Utah Juniper-Black Sagebrush Group. The Utah juniper-black sagebrush group occupies 48 percent of WJ-5 and is located on steep slopes. Other plants important to the group are low rabbitbrush, shadscale, galleta grass, Utah sweetvetch, Indian ricegrass, bluebunch wheatgrass, green rabbitbrush, and broom snakeweed. Plant cover is less than 20 percent. Juniper tree height is 2 to 3 m, while understory plant height is 10 to 30 cm.

C. Big Sagebrush Group. This minor group is essentially the same as the juniper-big sagebrush association except for the lack of Utah juniper. This association is 4 percent of the rodent trapping grid. Common plants are big

sagebrush, low rabbitbrush, shadscale, galleta grass, Utah sweetvetch, Indian ricegrass, green rabbitbrush, rock goldenrod, and cheatgrass. Plant cover and height are 25 percent and 50 cm, respectively.

D. Black Sagebrush Group. The black sagebrush group is essentially the same as the juniper-black sagebrush vegetal group except for Utah juniper. This association is 21 percent of the grid. Common plants are low rabbitbrush, shadscale, galleta grass, Utah sweetvetch, Indian ricegrass, green rabbitbrush, rock goldenrod, and cheatgrass. Plant cover is 20 percent with height less than 30 cm.

E. Wash Area. A major wash runs north and south through the western portion of the grid. It is also used for vehicular travel. The wash occupies 1 percent of WJ-5.

A.1.3 Shadscale Vegetation Type

The shadscale vegetation type dominates the oil shale tract Ub. This type is dissected by the riparian vegetation type along Evacuation Creek. Elevation ranges from 4500 m to 4860 m. The riparian vegetation type is adjacent to shadscale along the White River. In the southwestern corner of Ub, the shadscale and juniper vegetation types interface. Two rodent trapping grids, WS-1 and WS-4, are located within this vegetation type.

This vegetation type is readily recognized by the presence of shadscale. Big sagebrush is a sub-dominant shrub throughout the shadscale vegetation type. The other associated shrubs are spiny hopsage, greasewood, cottonthorn horsebrush, winterfat, and bud sage. Perennial herbaceous plants include bottlebrush squirreltail, Indian ricegrass, needle-and-thread grass, milkvetch, Utah sweetvetch, globemallow, and mentzelia. The annual plants are

cheatgrass, Douglas chaenatis, blue mustard, pinnate tansymustard, draba, gilia, halogeton, Russian thistle, prairie pepperweed, annual stickweed, desert Indianwheat, and tumble mustard. Cheatgrass is common and may form pure stands within the shrub interspaces.

The shadscale vegetation type has been greatly disturbed by livestock grazing as indicated by large amounts of cheatgrass, hedged shrubs, and perennial grasses growing in the canopy of shrubs. The rangeland is used for winter sheep grazing and is in poor condition. Surface erosion is evident at many localities.

A.1.3.1 WS-1. WS-1 is located in the Evacuation Creek area. Shadscale is the dominant shrub of the trapping grid (Table A.1.1-2). The other shrubs on the grid are big sagebrush, spiny hopsage, bud sage, winterfat, littleleaf brickella, cottonthorn horsebrush, and greasewood. Thick cheatgrass growth is abundant throughout the grid. Total plant cover is about 50 percent (Table B.1.1-3). Annual plant cover is approximately 25 percent while perennial cover is 28 percent. Six vegetal groups compose the rodent trapping grid:

A. Shadscale Group. The shadscale group occupies the majority of WS-1 at 49 percent. Shadscale is the dominant species with big sagebrush the subdominant. The other shrubs are cottonthorn horsebrush, winterfat, and spiny hopsage. Cheatgrass is abundant. Plant cover is 50 percent. Plant height is 40 and 20 cm, respectively, for the shrub canopy and understory plants.

B. Big Sagebrush Group. The big sagebrush group runs north and south along a minor drainage and occupies 15 percent of the grid. Big sagebrush is the most common shrub. Shadscale and greasewood are minor components. Cheat-

grass growth is abundant. Shrub canopy height is 50 cm, and cheatgrass height is 30 cm. Plant cover is approximately 50 percent.

C. Shadscale-Big Sagebrush Group. This group occupies 8 percent of WS-1 and is located in the western part of the grid. Shadscale and big sagebrush are the major species. Spiny hopsage, greasewood, and cottonthorn horsebrush are sparse. Cheatgrass is abundant. Plant cover is about 50 percent. Shrub and cheatgrass heights are, respectively, 50 and 25 cm.

D. Cottonthorn Horsebrush-Cheatgrass Group. This group is located on slopes with a southern exposure and occupies 18 percent of WS-1. Cottonthorn horsebrush and cheatgrass are the common plants. A few big sagebrush plants occur in the association. Plant cover is about 25 percent. Shrub height is 50 cm, and cheatgrass height is 20 cm.

E. Big Sagebrush-Shadscale Group. This vegetal group is located in the northwestern corner, northeastern corner, and the eastern part of WS-1 in small stands. Big sagebrush is the dominant shrub and shadscale the subdominant. Other shrubs are spiny hopsage, winterfat, and cottonthorn horsebrush. Cheatgrass is abundant. Plant cover is approximately 60 percent. Shrub canopy height is 50 cm, while cheatgrass height is 30 cm. This vegetal group occupies 9 percent of WS-1.

F. Bull Thistle Group. Bull thistle is the dominant plant. The bull thistle group occurs on shale outcrop and occupies 6 percent of the grid. Shadscale, big sagebrush, and broom snakeweed occur here and there. Plant cover is less than 10 percent with plant height less than 20 cm.

A.1.3.2 WS-4. The rodent trappng grid, WS-4, is situated on a terrace south of the White River. Unlike WS-1, cheatgrass is sparse. Also, shadscale

plant size is much reduced in comparison with those of WS-1. Recently, a large portion of the grid was disturbed by vehicular travel.

Big sagebrush is the dominant shrub of the trapping grid (Table A.1.1-2). The other shrubs are shadscale, greasewood, cottonthorn horsebrush, littleleaf brickellia, low rabbitbrush, rubber rabbitbrush, and mountain mahogany. The herbaceous plants are galleta grass, Indian ricegrass, bottlebrush squirreltail, hoary aster, cheatgrass, and globemallow. Albeit, herbaceous growth is sparse. Perennial and annual plant cover are respectively 18 and 2 percent (Table A.1.1-2). This rodent trapping grid is composed of four vegetal groups:

A. Big Sagebrush-Shadscale Group. The big sagebrush-shadscale group occupies 65 percent of WS-4 and occurs throughout the trapping grid. Big sagebrush and shadscale are the dominant shrubs. The other shrubs are rubber and low rabbitbrush, cottonthorn horsebrush, spiny hopsage, and greasewood. Understory plants are sparse. Shrub canopy height is 50 cm. Plant cover is 25 percent.

B. Shadscale-Big Sagebrush Group. The shadscale-big sagebrush group fingers into the grid along the northern boundary. It occupies 13 percent of WS-4. Shadscale and big sagebrush are the common shrubs. Low rabbitbrush is also present. Plant cover is approximately 25 percent. Shrub height is about 40 cm.

C. Utah Juniper-Big Sagebrush Group. This group occupies 13 percent of WS-4 and is an extension of the juniper vegetation type into the trapping grid. It occurs mainly in the southern portion of WS-4. Utah juniper and big sagebrush are the diagnostic plants. Low rabbitbrush, shadscale, and littleaf

brickellia are the other shrubs in the association. Plant cover is approximately 15 percent. Tree and shrub height are, respectively, 3 m and 35 cm.

D. Rock. Rock outcrops occupy 9 percent and are found throughout WS-4. Pockets of shallow soil support such plants as broom snakeweed, mountain mahogany, low rabbitbrush, and littleleaf brickellia. Plant cover is less than 5 percent.

A.1.4 Riparian Vegetation Type. The riparian vegetation type is located along the White River and Evacuation Creek. The White River flows westerly along the northern boundary of Ua and Ub. Evacuation Creek flows northerly through Ub dividing the shadscale vegetation type. The White River, adjacent to Ub, also divides the shadscale vegetation type. As the White River flows by Ua, it separates the sagebrush-greasewood and shadscale vegetation types. The three rodent trapping grids, WR-1, WR-2, and WR-4, are located along the White River.

Fremont poplar is diagnostic of the riparian vegetation type. Other characteristic plants include fivestamen tamarisk and coyote willow. At times, fivestamen tamarisk grows in thick, dense clumps. Coyote willow is not as common as Fremont poplar and fivestamen tamarisk. Associated shrubs are basin big sagebrush, greasewood, rubber rabbitbrush, spreading rabbitbrush, and skunkbush sumac. The important grasses and grasslike plants are western wheatgrass, Kentucky bluegrass, saltgrass, alkali muhly, alkali sacaton, common reedgrass, cheatgrass, sixweeks fescue, wirerush, horsetail, and sedge. At many localities, cheatgrass is the dominant grass. The forbs are bastard toadflax, ragweed, Louisiana sage, poverty weed, lambsquarter, yellow

spiderflower, bee spiderflower, blue mustard, clasping pepperweed, pinnate tansymustard, annual stickweed, and tumble mustard.

The riparian vegetation type is structurally more complex than the upland vegetation types. Fremont poplar provides a tree canopy approximately 20 to 30 m high. The next vegetation layer is composed of shrubs which vary in height from 0.75 to 1.5 m. Fivestamen tamarisk plants reach a height of 3 m, but they do not grow under the Fremont poplar canopy. The third layer of vegetation is the herbaceous layer which reaches a height of 30 to 40 cm.

The riparian vegetation is important for deer and cattle grazing. Deer utilize the vegetation throughout the year for forage and cover. Cattle grazing occurs from June through September. The range condition varies from poor to fair.

A.1.4.1 WR-1. The rodent trapping grid, WR-1, is located approximately 1.0 km upstream from Southam Canyon on the north side of the river. The southeast corner of the grid is frequently flooded during spring high water flow.

Fremont poplar trees are the dominant feature of the vegetation (Table B.1.1-2). The tree canopy almost covers the entire grid. Rubber rabbitbrush and spreading rabbitbrush are the dominant shrubs. Kentucky bluegrass, cheatgrass, and western wheatgrass make up the herbaceous understory. Cheatgrass is common throughout the grid. Total plant cover is 70 percent with perennial plants providing 28 percent cover (Table A.1.1-3). Three plant associations comprise the vegetation of WR-1:

A. Fremont Poplar Group. The Fremont poplar group occupies the largest portion of WR-1 at 56 percent. Fremont poplar trees are diagnostic of the

plant group. Rubber rabbitbrush and spreading rabbitbrush comprise the shrub canopy. A few greasewood plants are also present. The grass layer is composed of western wheatgrass, Kentucky bluegrass, and cheatgrass. Poplar trees are approximately 30 m tall and provide 50 percent cover. The shrub layer is 1.0 m tall and provides 15 percent cover. The grass layer provides 20 percent cover with a height of 50-75 cm before cattle grazing begins.

2. Rabbitbrush-Western Wheatgrass Group. This group occupies 23 percent of WR-1. It is the same as the Fremont poplar group except for the lack of trees. Rubber and spreading rabbitbrush comprise the dominat shrubs. Western wheatgrass and Kentucky bluegrass are the important perennial grasses; cheatgrass, as usual, is present. Plant cover approaches 70 percent. Shrub and grass height is 1.0 m and 40 cm, respectively.

3. Fivestamen Tamarisk Group. The fivestamen tamarisk group is located along the southern and eastern boundaries. The portion along the eastern boundary is a narrow 5 m wide strip. The tamarisk association occupies 21 percent of WR-1. The characteristic plant is fivestamen tamarisk, which can grow in thick, dense clumps. Rubber and sreading rabbitbrush are also present. The grasses of the association are saltgrass, cheatgrass, Kentucky bluegrass, western wheatgrass, and sixweeks fescue. Wiregrass and horsetail are two grasslike plants that are present. Fremont poplar and fivestamen tamarisk seedlings are common in the open spaces. Plant cover is 60 percent. Fivestamen tamarisk plant height reaches 3 m. The average height of the grasses is about 30 cm.

A.1.4.2 WR-2. The rodent trapping grid, WR-2, is located across the river from Southam Canyon. The vegetation has been greatly overgrazed and

trampled by livestock. An old cabin is located not far from the grid. A jeep trail runs across the rabbitbrush-western wheatgrass vegetal group.

Fremont poplar trees cover the southeastern portion of the grid (Table B.1.1-2). Rubber and spreading rabbitbrush are the important shrubs. Tamarisk, a tall growing shrub, occurs along the western border. Greasewood also occurs within WR-2. The common grasses are Kentucky bluegrass, western wheatgrass, alkali muhly, and cheatgrass. Total plant cover is approximately 50 percent, being equally divided among the annual and perennial plants (Table A.1.1-3). Six vegetal groups comprise the vegetation of WR-2:

A. Fremont Poplar Group. The Fremont poplar association is located in the southeastern part of the grid and occupies 38 percent of the total vegetation. Fremont poplar trees are diagnostic of the association. Other common plants include western wheatgrass, Kentucky bluegrass, cheatgrass, and spreading and rubber rabbitbrush. Total plant cover is approximately 70 percent. Plant height for the tree, shrub, and grass layers are 25 m, 75 cm, and 20-50 cm, respectively. Grass height varies because of livestock grazing and trampling.

B. Rabbitbrush-Western Wheatgrass Group. The rabbitbrush-western wheatgrass vegetal group occupies 34 percent and is located centrally within the grid. This group is traversed by a jeep trail. Spreading and rubber rabbitbrushes are the most common shrubs. Other woody plants are greasewood and coyote willow. The grasses are cheatgrass, western wheatgrass, and Kentucky bluegrass. Plant cover is aproximately 50 percent. Plant height for the rabbitbrushes is 50-75 cm and grasses 20-30 cm.

C. Rubber Rabbitbrush and Greasewood Group. The rubber rabbitbrush and greasewood vegetal group consists of large shrub clumps. The group is found in the northeastern corner and occupies 8 percent of WR-2. Rubber rabbitbrush and greasewood are the common shrubs with one skunkbush sumac plant also being present. Plant cover is approximately 50 percent, and plant height is 1.5 m.

D. Fivestamen Tamarisk Group. This group is located along the western boundary near the White River and occupies 12 percent of WR-2. The characteristic plant is fivestamen tamarisk which grows in thick clumps. Other associated plants are the rabbitbrushes, greasewood, western wheatgrass, saltgrass, cheatgrass, and Kentucky bluegrass. Grass growth is not as vigorous in this association as in the others. Plant cover is about 45 percent. Shrub height varies from 1 to 2 m. Grass height is 30 cm.

E. Spreading Rabbitbrush Group. This vegetal group is located in the northwestern corner of WR-2 and occupies 5 percent of the grid. Spreading rabbitbrush is the sole shrub. Plant cover is high at 80 percent. Plant height is 1.25 m. Cheatgrass plant growth is sparse under the shrub canopy.

F. Western Wheatgrass-Kentucky Bluegrass Group. This minor vegetal group occupies 4 percent and is situated along the eastern boundary of WR-2. The vegetal group is composed entirely with western wheatgrass, Kentucky bluegrass, and cheatgrass. Plant cover and height are 50 percent and 30 cm, respectively.

A.1.4.3 WR-4. The trapping grid WR-4 is located on the south side of the White River approximately 1.0 km west of WR-2. WR-4 is not as accessible as WR-1 and WR-2; therefore, it is not as greatly disturbed by livestock grazing and vehicular travel.

Fremont poplar trees occur throughout the grid (Table A.1.1-2). The shrub layer is composed of rubber rabbitbrush. Spreading rabbitbrush is not as common as on WR-1 and WR-2. The herbaceous layer is composed of western wheatgrass, Kentucky bluegrass, and cheatgrass. Total plant cover is 60 percent with perennial plants providing 48 percent cover (Table A.1.1-3). Three vegetal groups are found within the trapping grid:

A. Fremont Poplar Group. The Fremont poplar group occupies 51 percent and occurs throughout WR-4. The striking feature of this plant group is the Fremont poplar trees. Rubber rabbitbrush is the dominant shrub of the understory. The important grasses are western wheatgrass, Kentucky bluegrass, and cheatgrass. Total plant cover is approximately 60 percent. The tree canopy height is 25 m. The shrub and grass layer heights are, respectively, 60 and 30 cm.

B. Rabbitbrush-Western Wheatgrass Group. The lack of trees distinguishes this group from the Fremont poplar association. The rabbitbrush-western wheatgrass association occurs throughout the trapping grid and occupies 41 percent of it. Rubber rabbitbrush is the dominant shrub. A few spreading rabbitbrush and greasewood shrubs are present, also. Western wheatgrass, Kentucky bluegrass, and cheatgrass are the important grasses. Plant cover is 60 percent. Shrub and grass heights are 80 and 30 cm, respectively.

C. Fivestamen Tamarisk Group. Fivestamen tamarisk is characteristic of this plant group. Spreading and rubber rabbitbrush also are present. The graminoids include saltgrass, sixweeks fescue, western wheatgrass, Kentucky bluegrass, cheatgrass, and horsetail. Plant cover is 50 percent. Shrub and grass heights are, respectively, 2.0 m and 30 cm.

A.1.5 Literature Cited

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Table A.1.1-1 Plant species occurring on the 10 rodent trapping grids at Ua-Ub.

Botanical Name	Common Name
WOODY PLANTS	
Artemisia frigida	Fringed sagebrush
A. nova	Black sagebrush
A. spinescens	Bud sage
A. tridentata ssp. *tridentata*	Basin big sagebrush
A. tridentata ssp. *wyomingesis*	Wyoming big sagebrush
Atriplex confertifolia	Shadscale
Brickellia microphylla	Littleleaf brickellia
Ceratoides lanata	Winterfat
Cercocarpus montanus	Mountain mahogany
Chrysothamnus greenei	Greenes rabbitbrush
C. linifolius	Spreading rabbitbrush
C. nauseosus	Rubber rabbitbrush
C. viscidiflorus	Low rabbitbrush
Eriogonum microthecum	Slenderbush eriogonum
Grayia spinosa	Spiny hopsage
Juniperus osteosperma	Utah juniper
Leptodactylon pungens	Prickly phlox
Pinus edulis	Pinyon pine
Populus fremontii	Fremont poplar
Rhus trilobata	Skunkbush sumac
Salix exigua	Coyote Willow
Sarcobatus vermiculatus	Greasewood
Tamarix parvifolia	Fivestamen tamarisk
Tetradymia spinosa	Cottonthorn horsebrush
Xanthocephalum sarothrae	Broom snakeweed
GRASSES	
Agropyron smithii	Western wheatgrass
A. spicatum	Bluebunch wheatgrass
Bromus tectorum	Cheatgrass
Cenchrus pauciflorus	Sandbur
Distichlis spicata	Inland saltgrass
Hilaria jamesii	Galleta grass
Muhlenbergia asperifolia	Alkali muhli
Oryzopsis hymenoides	Indian ricegrass
Phragmites communis	Common reed
Poa pratensis	Kentucky bluegrass
Sitanion hystrix	Bottlebrush squirreltail

Botanical Name	Common Name
GRASSES (CONTINUED)	
Sporobolus airoides	Alkali sacaton
Stipa comata	Needle-and-thread grass
Vulpia octoflora	Sixweeks fescue
GRASSLIKE PLANTS	
Carex spp.	Carex
Juncus spp.	Wirerush
Equisetum laevigatum	Smooth horsetail
FORBS (ANNUAL)	
Ambrosia acanthicarpa	Rayweed
Chaenaetis douglasii	Douglas chaenaetis
Chenopodium album	Lambsquarter
Chorispora tenella	Blue mustard
Cleome lutea	Yellow spiderflower
C. serrulata	Bee spiderflower
Cryptantha spp.	Cryptantha
Descurainia pinnata	Pinnate Tansymustard
D. sophia	Flixweed Tansymustard
Draba cuneifolia	Draba
Eriogonum spp.	Eriogonum
Gila polycladon	Gilia
G. sinuata	Gilia
Halogeton glomeratus	Halogeton
Lappula occidentalis	Annual stickweed
Lepidium densiflorum	Prairie pepperweed
L. perfoliatum	Clasping pepperweed
Mentzelia albicaulis	White-stem mentzelia
Plantgo insularis	Desert Indianwheat
Salsola pestifer	Russian thistle
Sisymbrium altissimum	Tumblemustard
FORBS (PERENNIAL)	
Arabis sp.	Rockcress
Artemisia ludoviciana	Louisiana sage
Astragalus sp.	Milkvetch
Cirsium vulgare	Bull thistle
Comandra pallida	Bastard toadflax
Erigeron engelmanni	Engelmann fleabane

Botanical Name	Common Name
FORBS (PERENNIAL) (CONTINUED)	
Eriogonum sp.	Eriogonum
Euphorbia fendleri	Fendler euphorbia
Hedysarum boreale	Utah sweetvetch
Iva axillaris	Povertyweed
Lepidium montanum	Mountain pepperweed
Lomatium spp.	Desert parsley
Machaeranthera canescens	Hoary aster
Petradoria pumila	Rock goldenrod
Phacelia sp.	Phacelia
Phlox hoodii	Hoods phlox
Sphaeralcea coccinea	Scarlet globemallow
S. parvifolia	Globemallow
Suaeda torreyana	Torrey seepweed
Thelypodium sagittatum	Thelypody

Table A.1.1-2 Cover, density, frequency, and importance values for the perennial plants found within each rodent trappng grid.

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative Cover	% Relative Density	% Relative Freq.	Importance Value[1]
WG-1	Greasewood	Big sagebrush	6.1	4444	29.6	27.9	40.0	30.7	98.6
		Spiny hop-sage	7.4	2963	29.6	33.8	26.7	30.7	91.2
		Greasewood	7.8	2963	29.6	35.5	26.7	30.7	92.9
		Cottonthorn horsebrush	0.6	370	3.7	2.5	3.3	3.8	9.6
		Fendler euphorbia	0.1	370	3.7	0.2	3.3	3.8	7.3
WG-2	Greasewood	Big sagebrush	9.2	8000	40.0	38.5	35.3	31.6	105.4
		Low rabbit-brush	2.7	1667	16.7	11.2	7.4	13.2	31.8
		Prickly phlox	0.1	333	3.3	0.1	1.5	2.6	4.2
		Cottonthorn horsebrush	1.5	333	3.3	6.2	1.5	2.6	10.3
		Shadscale	0.5	333	3.3	2.1	1.5	2.6	6.2
		Broom snakeweed	1.7	5667	13.3	2.1	25.0	2.6	29.7
		Black sagebrush	2.7	3333	16.7	11.2	14.7	13.2	39.1
		Greasewood	2.7	1667	16.7	11.3	7.4	13.2	31.9

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative			Importance Value[1]
						Cover	Density	Freq.	
WG-2	Greasewood	Spiny hopsage	2.7	333	3.3	11.2	1.5	2.6	15.3
		Utah sweetvetch	0.1	333	3.3	0.1	1.5	2.6	4.2
		Green rabbitbrush	0.2	333	3.3	0.7	1.5	2.6	4.8
		Fendler euphorbia	0.1	333	3.3	0.1	1.5	2.6	4.2
WG-3	Greasewood	Big sagebrush	4.2	4333	16.7	40.9	52.0	31.3	124.2
		Greasewood	4.5	2333	20.0	44.4	28.0	37.5	109.9
		Fringed sage	0.1	333	3.3	0.3	4.0	6.2	10.5
		Rubber rabbitbrush	0.5	333	3.3	4.4	4.0	6.2	14.6
		Cottonthorn horsebrush	0.8	333	3.3	8.2	4.0	6.2	18.4
		Desert parsley	0.1	667	6.7	1.3	8.0	12.5	21.8

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative			Importance Value[1]
						Cover	Density	Freq.	
WJ-1	Juniper	Big sagebrush	12.6	9000	53.3	51.3	27.3	27.6	106.2
		Black sagebrush	2.5	6000	26.7	10.0	18.2	13.8	42.0
		Broom snakeweed	0.7	5000	26.7	3.0	15.2	13.7	31.9
		Galleta grass	0.3	4333	13.3	1.2	13.1	6.9	21.1
		Shadscale	0.3	1000	10.0	1.2	3.0	5.2	9.4
		Indian ricegrass	0.4	3000	23.3	1.6	9.1	12.1	22.8
		Cryptantha	0.1	1333	10.0	0.5	4.0	5.2	9.7
		Utah juniper	6.3	333	3.3	1.4	1.0	1.7	4.1
		Fendler euphorbia	0.1	667	6.7	0.3	2.0	3.4	5.7
		Rabbit rubberbrush	0.3	333	3.3	1.4	1.0	1.7	4.1
		Utah sweetvetch	0.3	1000	6.7	1.0	3.0	3.4	7.4
		Slenderbush erigonum	0.1	333	3.3	0.1	1.0	1.7	2.8
		Prickly phlox	0.1	667	6.7	0.3	2.0	3.4	5.7
		Greasewood	0.5	0	0	2.0	0	0	2.0

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative Cover	% Relative Density	% Relative Freq.	Importance Value[1]
WJ-5	Juniper	Black sagebrush	3.8	6667	40.0	18.5	20.2	22.2	60.9
		Utah juniper	5.9	333	3.3	28.3	1.0	1.9	31.2
		Slender-bush eriogonum	0.2	1667	13.3	0.8	5.1	7.4	13.3
		Big sagebrush	7.6	5333	33.3	36.6	16.2	18.5	71.3
		Rubber rabbitbrush	0.7	667	6.7	3.2	2.0	3.7	8.9
		Broom snakeweed	0.7	2667	20.0	3.2	8.0	11.1	22.3
		Galleta grass	0.4	5333	16.7	1.9	16.2	9.3	27.4
		Shadscale	0.3	333	3.3	1.6	1.0	1.9	4.5
		Green rabbitbrush	0.2	333	3.3	0.8	1.0	1.9	3.7
		Littleleaf brickellia	0.3	1000	3.3	1.6	3.0	3.3	7.9
		Fendler euphorbia	0.2	2333	10.0	1.0	7.0	5.6	13.6
		Bluebunch wheatgrass	0.1	0	0	0.2	0	0	0.2

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative Cover	% Relative Density	% Relative Freq.	Importance Value[1]
WJ-5	Juniper	Gilia	0.1	3333	3.3	0.2	10.1	1.9	12.2
		Greasewood	0.1	0	0	0.5	0	0	0.5
		Indian ricegrass	0.1	667	6.7	0.3	2.0	3.7	6.0
		Rock goldenrod	0.1	333	3.3	0.2	1.0	1.9	3.1
		Utah sweetvetch	0.1	333	3.3	0.2	1.0	1.9	3.1
		Thelypody	0.1	1000	10.0	0.5	3.0	5.6	9.1
		Prickly phlox	0.1	667	3.3	0.3	2.0	1.9	4.2
WS-1	Shadscale	Big sagebrush	7.8	6333	33.3	29.0	29.7	23.2	81.9
		Shadscale	14.3	8666	56.7	53.0	40.6	39.5	150.3
		Bud sage	0.1	333	3.3	0.4	1.6	2.3	4.3
		Winterfat	0.6	2333	20.0	2.1	10.9	14.0	27.0
		Littleleaf brickellia	0.2	667	3.3	0.6	3.1	2.3	6.0
		Cottonthorn horsebrush	1.9	1667	16.7	6.9	7.8	11.6	26.3
		Greasewood	2.2	1333	10.0	8.0	6.2	7.0	21.2

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative Cover	% Relative Density	% Relative Freq.	Importance Value[1]
WS-4	Shadscale	Big sagebrush	11.2	7667	50.0	62.9	43.4	41.7	148.0
		Greasewood	1.0	1000	10.0	5.4	5.7	8.3	19.4
		Shadscale	3.2	6000	30.0	17.9	34.0	25.0	76.9
		Hoary aster	0.1	1000	10.0	0.7	5.7	8.3	14.7
		Cottonthorn horsebrush	1.9	333	3.3	1.9	1.9	2.8	6.6
		Littleleaf brickellia	0.2	333	3.3	0.9	1.9	2.8	5.6
		Low rabbit-brush	1.0	667	6.7	5.6	3.8	5.6	15.0
		Mountain mahogany	0.5	333	3.3	2.8	1.9	2.8	7.5
		Rubber rabbitbrush	0.3	333	3.3	1.9	1.9	2.8	6.6
WR-1	Riparian	Rubber rabbitbrush	7.2	2333	23.3	25.8	6.0	31.8	63.6
		Fremont poplar	13.3	0	0	47.6	0	0	27.5
		Kentucky bluegrass	1.0	4000	10.0	3.6	10.3	13.6	27.5
		Western wheatgrass	5.3	29333	30.0	19.0	75.2	40.9	75.1

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative Cover	% Relative Density	% Relative Freq.	Importance Value[1]
WR-1	Riparian	Spreading rabbitbrush	1.0	2000	6.7	3.6	5.1	9.0	17.7
		Desert parsley	0.1	1333	3.3	0.4	3.4	4.5	8.3
WR-2	Riparian	Greasewood	0.1	0	0	0.4	0	0	0.4
		Fremont poplar	13.0	333	3.3	52.6	2.1	5.6	60.3
		Alkali muhly	0.1	667	3.3	0.4	4.2	5.6	10.2
		Kentucky bluegrass	2.2	2667	6.7	8.8	16.7	11.1	36.6
		Western wheatgrass	1.7	5333	13.3	7.0	33.3	22.2	62.5
		Rubber rabbrush	2.7	1667	16.7	10.8	10.4	27.8	49.0
		Spreading rabbitbrush	3.3	5000	13.3	13.4	31.3	22.2	66.9
		Fivestamen tamarisk	1.7	333	3.3	6.7	2.1	5.6	14.4
WR-4	Riparian	Fremont poplar	16.0	667	6.7	33.7	0.4	5.6	39.7
		Western wheatgrass	21.3	168667	63.3	44.9	92.8	52.8	161.0

Rodent Trapping Grid	Vegetation Type	Species	Cover %	Density No./Ha	Frequency %	% Relative Cover	% Relative Density	% Relative Freq.	Importance Value[1]
WR-4	Riparian	Rubber rabbitbrush	8.2	2667	23.3	17.2	1.5	19.4	38.1
		Spreading rabbitbrush	0.3	667	6.7	0.7	0.4	5.6	6.7
		Kentucky bluegrass	1.7	9000	20.0	3.6	5.0	16.7	25.3

[1]Imporance value = relative cover + relative density + relative frequency.

Table A.1.1-3 Percent bare ground, rock, litter, annual, and perennial plant cover and total plant cover for the rodent-trapping grids at Ua-Ub.[1]

Rodent Trapping Grid	Vegetation Type	Percent Ground Cover					
		Bare Ground	Rock	Litter	Annual Plant Cover	Perennial Plant Cover	Total Plant Cover
WG-1	Greasewood	44.6	2.7	12.5	19.5	22.0	40.6
WG-2	Greasewood	41.9	27.2	5.0	2.4	24.1	25.3
WG-3	Greasewood	29.3	0.7	11.6	49.5	10.2	58.7
WJ-1	Juniper	37.1	29.0	9.7	0.6	24.5	24.1
WJ-5	Juniper	47.7	24.0	7.5	0.3	20.7	21.1
WS-1	Shadscale	33.1	11.5	6.8	21.7	27.0	48.4
WS-4	Shadscale	61.7	11.8	6.4	1.5	17.9	19.9
WR-1	Riparian	11.2	0	19.1	59.8	27.9	69.5
WR-2	Riparian	36.9	0	14.9	35.4	24.7	47.8
WR-4	Riparian	8.7	0	30.7	28.2	47.5	60.5

[1]Data were collected October 5-7, 1983.

APPENDIX B

B.1 SOIL TAXONOMY

B.1.1 Soil Classification

Soils are classified according to criteria presented in Soil Taxonomy (USDA-SCS, 1975). Soil orders described in this survey are Entisols and Aridisols. These orders are differentiated by the degree of soil development (pedogenic development) as described for soil morphology. Entisols are soils with little or no pedogenic development. Aridisols are soils which include one or more pedogenic horizons. Taxonomic criteria used for subsequent classifications to the subgroup level include:

- Mode of soil formation.
- Type(s) of genetic horizon(s) (if present).
- Soil moisture regime.
- Soil temperature regime.
- Depth of soil.

Brief descriptions of distinguishing taxonomic criteria to the Subgroup level are presented in Table B.1.1-1.

At the family taxonomic level, taxa are differentiated based on soil texture, minerology, and soil temperature regime. The textural class of soils described range from fragmental to fine-loamy. All soils are of mixed minerology and most are calcareous. Parent materials include members of Uinta and Green River formations. The soil temperature regime is cryic.

Table B.1.1-1. Distinguishing taxonomic criteria to the subgroup level.

Order / Suborder / Group / Subgroup	Distinguishing Criteria
Entisols	little genetic development
Orthent	formed in place
Torriorthent	aridic moisture regime
Typic	typical of group
Lithic	shallow soil
Fluvent	fluventic deposition
Torrifluvent	aridic moisture regime
Typic	typical of group
Ustifluvent	ustic moisture regime
Typic	typical of group
Aquic	wetter than typical
Aridisol	subsurface genetic horizon(s)
Argid	illuvial clay horizon
Natriargid	influenced by sodium
Typic	typical of group
Orthid	no illuvial clay horizon
Camborthid	cambic horizon
Typic	typical of group

B.1.2 Map Unit Descriptions

Map units are associations and complexes of slope phases of soil families and miscellaneous land types. Map units are delineated for each of ten grids in Figures 5.4-1 to 5.4-4, Section 5.4. The map unit legend is presented in Table B.1.2-1. Detailed profile descriptions for dominant components of map units are presented with respect to soil taxa.

B.1.2.1 (W) Wash. This land type is described in grids WJ-5, WG-1, WG-2, and WG-3. Generally, washes are eroded forms of contiguous soil types. They are affected by infrequent flooding. The depth of washes varies from less than 50 cm to greater than 2 meters in grid WG-3. Vehicular traffic is a frequent form of additional disturbance in washes.

B.1.2.2 (D) Disturbed. A single delineation of this land type is described for grid W-G3. The area is a graded road. A pipeline has been constructed parallel to the road. Characteristics of this miscellaneous area are similar to subsurface strata of contiguous soil types.

B.1.2.3 (R1) Sandstone Bedrock. This miscellaneous land type comprises mapable areas in grid WS-4. It is a component of complex map units in WJ-1, WJ-5, and G3. Sandstone bedrock of the Uinta Formation occupies the highest positions of WS-4. Included in delineations are areas with thin surface accumulations of soil material. These are mostly recently weathered ephemeral deposits and are in transit to lower landscape positions.

Surfaces are effectively impermeable to water except in widely spaced fractures. Runoff is very rapid. Vegetation is essentially lacking except for a few junipers at the periphery of delineations.

Table B.1.2-1 Map unit legend for soils in 10 rodent trapping grids, Oil Shale Tracts, Ua-Ub.

Map Unit Symbol	Map Unit
D	Disturbed
R1	Sandstone bedrock
R2	Shale bedrock
W	Wash
11Kbc	Loamy-skeletal, lithic torriorthent, 3-15% slope
12Kd	Fragmental, lithic torriorthent, shale substatum, 15-25% slope
13Xde	Fragmental, lithic torriorthent/talus/rock outcrop complex, 25-65% slope
14Xc	Fragmental, lithic torriorthent/rock outcrop complex, 5-25% slope
21bc	Coarse-loamy, moderately deep, typic torriorthent, 3-5% slope
22b	Coarse-loamy, deep, typic torriorthent, 3-5% slope
22Kbc	Loamy-skeletal, deep, typic torriorthent, 3-15% slope
31a	Sandy, typic torrifluvent, 1-3% slope
32a	Sandy/coarse-loamy, typic torrifluvent, 2-3% slope
33ab	Coarse-loamy, typic torrifluvent, 2-5% slope
41b	Fine-loamy, typic natriargid, 3-5% slope
51b	Coarse-loamy, moderately deep, typic camborthid, 3-5% slope
61a	Coarse-loamy, typic ustifluvent, 1-3% slope
62a	Sandy, typic ustifluvent, 1-3% slope
63a	Coarse-loamy/fine-loamy typic ustifluvent, 0-2% slope
71a	Sandy/fine-loamy/sandy aquic ustifluvent, 0-3% slope
72a	Sandy aquic ustifluvent, 0-3% slope

These areas seem essentially unsuitable for habitation by burrowing rodents although rock fractures may comprise suitable niches.

B.1.2.4 (R2) Shale Bedrock. This miscellaneous land type occurs in grid WS-1. The dominant component is moderately weathered shale of the Green River Shale Formation. It occurs in convex, residual positions and is most common on southern exposures where erosion is most effective. Included in delineations are small areas with shallow accumulations of soil material. These comprise less than 10 percent of the map unit and occur at the periphery of delineations.

The named component is very excessively drained. Soft, moderately weathered shale which breaks to thin laminae extends from the surface to about 20 cm. Fine materials fill horizontal fractures and comprise less than 10 percent of the weathered strata. The substratum is hard, slightly weathered shale.

Infiltration and permeability to 20 cm are slow and runoff is very rapid. Vegetation is restricted to a few hardy, shallow-rooted species (thistle).

This landtype appears essentially unsuitable for habitation by burrowing rodents.

B.1.2.5 (11Kbc) Loamy-skeletal, Lithic Torriorthent (3-15% Slope). This map unit is described for grids WJ-1, WJ-5, WS-4, WG-1, WG-2, and WG-3. The named component comprises about 85 percent of delineations. Sandstone bedrock (WR-1) makes up approximately 5 percent of delineations and moderately deep Torriorthent soils (21bc) which occur mostly at downslope extremes make up about 10 percent of the map unit.

The dominant soil is shallow to very shallow and excessively drained. Typically, the surface layer is loose, channery sandy loam material about 6 cm thick. The subtending stratum is loose, very channery sandy loam about 17 cm thick. Extremely channery sandy loam overlies fractured sandstone bedrock at a depth of about 30 cm. The depth to fractured bedrock ranges from 17 to 50 cm for pedons described. Some surface materials are very channery and extremely channery.

Infiltration and permeability are rapid to very rapid to bedrock. Significant volumes of lateral flow probably occur over the bedrock. These soils receive appreciable run-on from adjacent bedrock outcrops. The effective rooting depth varies from 17 to 50 cm. Surfaces are slightly to moderately eroded by sheet wash.

Characteristics potentially limiting to rodent habitation include loose consistency of surface layers, high coarse-fragment composition, shallow depth to bedrock and high run-on of water from contiguous rock outcrops.

B.1.2.6 (12Kd) Fragmental, Lithic Torriorthent, Shale Substratum (15-25% Slope. This map unit is described for residual positions of grid WS-1. The dominant form is low hills which occur on the eastern portion of the grid. Less extensive delineations occur on narrow transitions between shale bedrock (R2) and moderately deep Torriorthent soils (21bc). These transitional areas are similar in most respects to the dominant form but slopes are less than 10 percent. The named component comprises about 85 percent of map unit delineations. Shale bedrock (WR-2) occurs on eroded positions and may comprise 5 percent of delineations. Moderately deep Torriorthents (21bc) occur at downslope transitions and may comprise 10 percent of delineations.

These soils are shallow and excessively drained. Typically the surface layer is channery sandy loam with loose consistency and is about 10 cm thick. The subsoil is loose, extremely channery sandy loam about 20 cm thick and overlies slightly weathered, fractured shale.

Infiltration and permeability are rapid to a depth below 30 cm. Runoff is moderate to rapid. Surfaces are moderately eroded by sheet wash and shale fragments comprise about 50 percent of the surface area. The effective rooting depth is about 30 cm.

Characteristics potentially limiting to burrowing rodents are high coarse fragment content, run-on from contiguous rock outcrop and shallow depth to bedrock.

B.1.2.7 (13Xde) Fragmental Torriorthent/Talus/Rock Outcrop Complex (25-65% Slope. This map unit occurs on steep canyon slopes of grid WJ-5. Sandstone rock outcrops occur on slope shoulder positions and form the steepest positions of arid aspects. Rock outcrops comprise about 20 percent of map unit delineations. Talus fields subtend rock outcrops and comprise about 30 percent of delineations. Fragmental Torriorthent soils (12K) occur on mesic aspects of more moderately sloping positions and comprise about 50 percent of delineations.

The Torriorthent soil is shallow and excessively drained. Typically the surface layer is sandy loam with greater than 65 percent (by volume) channers. Depth to sandstone bedrock is generally less than 30 cm but may extend to greater than 100 cm in depositional positions.

Infiltration and permeability are very rapid to the bedrock level and resticted to fracture planes below this depth. Runoff is rapid. Effective rooting depth ranges from 0 to 50 cm.

The broken surface and voids between coarse talus materials may constitute an opportune habitat for some rodent species. Burrowing species may be limited by unstable materials, high percentage of coarse fragments and shallow depth to bedrock.

This map unit includes all aspects of steep canyon slopes. Depth of snowpack, soil temperature, depth of frozen soil material and associated hydrologic characteristics are expected to vary considerably between aspects. On northern aspects snowpack is probably retained throughout much of the winter months, thus reducing both the thickness of the frozen soil layer and the frequency of freeze/thaw cycles. Southern aspects are expected to retain snowpack to a lesser degree, thus surface soils may experience frequent freeze/thaw cycles. The distribution of burrowing rodents on different aspects of map unit delineations may be affected by these microclimatic characteristics.

B.1.2.8 (14Xc) Fragmental Torriorthent/Rock Outcrop Complex (15-25% Slope). This map unit is described for ridgecrests and slopes with southern aspect in grid WJ-1. Sandstone bedrock occurs primarily on ridgecrest positions and comprises about 25 percent of delineations. Fragmental Torriorthent soil occurs mostly on sideslope positions and comprises about 60 percent of the map unit. Areas of shallow, loamy skeletal Torriorthent soil (11Kbc) occupy positions at the base of arid slopes and positions transitional from ridgecrests to more mesic slopes and make up about 15

percent of delineations.

The fragmental Torriorthent soil is shallow and excessively drained. Typically the surface layer is channery sandy loam about 10 cm thick. The subtending stratum is loose, extremely channery sandy loam about 20 cm thick and overlies hard, fractured sandstone bedrock.

The rock outcrop component is essentially impermeable to water except along fractures. Runoff is very rapid and generally towards southern aspects. Permeability for the Torriorthent soil is rapid to the bedrock layer and limited to fractures through this layer. Surface runoff is moderate and a high degree of lateral subsurface drainage is probable. Surfaces are moderately eroded by sheet wash. The effective rooting depth is about 30 cm for the Torriorthent soil.

Soil characteristics potentially limiting to habitation by burrowing rodents include high volumes of coarse fragments, a high degree of run-on for sideslope positions and shallow depth to bedrock. These positions are not expected to retain snowpack throughout winter months. Frequent freeze/thaw cycles may also affect rodent distributions.

B.1.2.9 (21bc) Coarse-loamy, Moderately Deep, Typic Torriorthent (3-10% Slope). This map unit occurs on the east and west portions of grid WS-1. The named component comprises about 60 percent of delineations. An eroded form of the named component occurs in interspaces between shrub canopies and comprises about 20 percent of delineations. Inclusions of deep Torriorthent soils (22b) occur toward the center of the grid and may comprise 15 percent of the map unit.

The named component is moderately deep and well drained. The soil described is from an uneroded position under a shrub canopy. Typically, the surface layer is sandy loam with about 5 percent fine gravel and is about 8 cm thick. The subtending layer is sandy loam with weak structure and extends to a depth of about 45 cm. The subtending strata are gravelly sandy loam with weak structure and overlie hard, unweathered shale bedrock at a depth of about 90 cm.

Infiltration and permeability are moderately rapid and runoff is slow. The effective rooting depth is about 90 cm. Surfaces are moderately eroded in the form of rills 25 to 75 cm deep which dissect areas into small islands protected by shrub canopies.

Soil characteristics appear favorable for burrowing rodent habitat. A significant volume of run-on from adjacent Lithic Torriorthents (12Kd) and bedrock exposures (R2) may result in unfavorably wet conditions for short periods following spring runoff and intense summer precipitation events.

B.1.2.10 <u>(22b) Coarse-loamy, Deep, Typic Torriorthent (3-5% Slope)</u>. This map unit is described for alluvial positions of grid WS-1. The named component comprises about 85 percent of delineations. Areas of moderately deep Torriorthent soil (21bc) occur at the flanks of the alluvial position and may comprise 15 percent of the map unit.

The dominant soil is deep and well drained. The surface layer is sandy loam material aggregated into weak to moderate ped structure. Substrata to a depth of 140 cm are sandy loam texture and incorporate small volumes of fine gravel. Slightly weathered, laminarly fractured shale underlies soil material at a depth of about 140 cm.

Infiltration and permeability are moderately rapid and runoff is slow. The effective rooting depth is about 140 cm. The surface relief is broadly concave and even. Surfaces are uneroded and constitute depositional positions for materials weathered from adjacent upland positions.

Soil characteristics appear favorable for habitation by burrowing rodents.

B.1.2.11 (22Kbc) Loamy-skeletal, Deep, Typic Torriorthent (3-15% Slope) Soils comprising this map unit form alluvial fans and aprons. Materials originate from weathering and erosion of adjacent upland positions. This map unit is identified in grids WJ-1, WJ-5, WG-2, and WG-3. The named component makes up about 75 percent of delineations. Lithic Torriorthent soils (11Kbc, 13X, or 14X) occur at transitions to upland slopes and comprise about 10 percent of the map unit. Deep Torriorthent and Torrifluvent soils (31a and 33ab) occur at downslope transitions and may comprise 15 percent of map unit areas.

The dominant component of this map unit is deep and well drained. Typically, the surface layer is sandy loam with soft consistence and is about 5 cm thick. Substrata are gravelly sandy loam with loose, soft and slightly hard consistence to a depth below 150 cm.

Infiltration and permeability are moderately rapid and runoff is slow. The effective rooting depth is greater than 150 cm. Some surfaces are slightly eroded by rill wash but most sites receive infrequent deposition.

Soil characteristics appear favorable for habitation by burrowing rodents.

B.1.2.12 (31a) Sandy, Typic Torrifluvent (1-3% Slope). This map unit is described for the alluvial position of grid WG-3. The named component comprises about 90 percent of the delineation. Loamy-skeletal Torriorthent soil (22Kbc) occurs at the upslope flanks of the delineation and makes up about 10 percent of the map unit.

The dominant component is very deep and somewhat excessively drained. The surface layer is loamy sand aggregated into weak structure. Substrata are loose loamy sand material with no discernable structure to depths well below 150 cm. Discontinuous lenses of skeletal and fragmental materials are common in the substrata.

Infiltration and permeability are rapid and runoff is very slow. The effective rooting depth is about 25 cm and is apparently limited by lack of available water below this depth. Surface materials appear uneroded but are probably frequently redistributed by aeolean forces. Asphalt Wash dissects the center of the single delineation.

The most apparent characteristic potentially limiting to habitation by burrowing rodents is loose consistence of both surface and subsurface materials althnough rodent burrows were noted in the cut bank of the wash central to grid WG-3.

B.1.2.13 (32a) Sandy/coarse-loamy, Typic Torrifluvent (2-3% Slope). This map unit is described for alluvial positions of grid WG-1. It occurs in somewhat protected positions which receive aeolean sediments eroded from surrounding sandstone bluffs. The named component comprises about 85 percent of delineations. Coarse-loamy Torrifluvent soils (33a) occur at the periphery of delineations and comprise about 15 percent of delineations.

The dominant component is deep and somewhat excessively to well drained. Typically, material to a depth of about 45 cm is loose loamy sand with weak or no structural development. This material appears to be aeolean in origin. Subtending material to a depth of over 150 cm is slightly gravelly sandy loam and of alluvial origin. Materials comprising these substrata are aggregated into weak to moderate structure.

Infiltration and permeability are rapid to a depth of about 45 cm and moderate below this depth. The effective rooting depth is greater than 150 cm. Surfaces are slightly eroded by rill wash and materials are probably frequently redistributed by wind.

Loose consistence of surface layers is the most apparent limitation to habitation by burrowing rodents. Surface materials are especially susceptible to redistribution by wind.

B.1.2.14 (33ab) Coarse-loamy, Typic Torrifluvent (2-5% Slope). This map unit is described for alluvial positions of grids WG-1 and WG-2. The named component comprises about 85 percent of the map unit. Inclusions of soil with sandy surface layers (32a) and small rill washes (W) comprise the remaining 15 percent of delineations.

The named component is deep and well drained. The surface layer is sandy loam material with soft to slightly hard consistence and is about 10 cm thick. Substrata to a depth of 100 cm are slightly gravelly sandy loam agregated into weak and moderate ped structure. Subtending material is loose, gravelly sandy loam to depths below 150 cm. Coarse-fragment composition generally increases with depth below 100 cm.

Infiltration and permeability are moderate and runoff is slow. The effective rooting depth is greater than 150 cm. Surfaces are moderately eroded by rill wash resulting in a slightly hummocky to undulating microtopography. The amplitude of the microtopography ranges from 25 to 40 cm. Interspaces between shrub canopies are essentially non-vegetated except for sparsely distributed cheatgrass. Gravel comprises greater than 30 percent of the surface area in intershrub corridors.

Soil characteristics appear favorable for habitation by burrowing rodents.

B.1.2.15 (41b) Fine-loamy, Deep, Xerollic Natriargid (3-5% Slope). This map unit is described for elongate, narrow, convex ridge-like positions of grid WS-4. The named component makes up about 90 percent of delineations. Coarse-loamy, moderately deep, Camborthid soils (51b) comprise about 10 percent of delineations in positions transitional to concave or even relief.

The dominant component is deep and moderately well drained. The surface layer is soft sandy loam material about 10 cm thick. Subtending horizons to a depth of about 50 cm is sandy clay loam aggregated into weak to moderate ped structure and is believed to be strongly influenced by sodium. Subtending material is silty clay loam with crystalline salts occuring in small pockets 1 to 3 mm in diameter. The substrata has sandy loam texture with reduced greenish hue and common bright mottles indicative of prolonged wetness. Moderately weathered sandstone bedrock with oxidized color occurs at a depth of 145 cm.

Infiltration into the surface horizon is moderate and permeability through subsurface strata is moderately slow to slow. Runoff is moderately

rapid. The reduced color of the substratum and presence of mottles with oxidized colors indicate prolonged wetness and poor aeration in the deepest strata. The effective rooting depth is about 105 cm. Surfaces are moderately eroded in shrub corridors resulting in a slightly hummocky microtopography. Cryptogamic crust is well developed under and immediately surrounding shrub canopies. The surface horizon is essentially absent in shrub corridors. These surfaces are crusted and light in color.

Relatively poor drainage may be a principal limitation to habitation of burrowing rodents. The soil is expected to remain moist longer than surrounding soil types.

B.1.2.16 (51b) Coarse-loamy, Moderately Deep, Xerollic Camborthid (3-5% Slope). This map unit is described for depositional positions in grid WS-4. The named component comprises about 85 percent of delineations. Shallow Torriorthent soil (11Kbc) occurs along transitions to residual positions and comprises about 10 percent of the map unit. Fine-loamy Natriargid soil (41b) comprises about 5 percent of delineations in narrow, elongate and convex residual positions.

The dominant soil is moderately deep and moderately well drained. Typically, the surface layer is sandy loam material aggregated into weak ped structure with soft consistence and is about 12 cm thick. The subsoil is sandy loam with slightly hard consistence and about 25 cm thick. The subtending layer to 55 cm is sandy loam material aggregated into weak ped structure with amorphous coatings of soluble salts on ped faces. The substratum is slightly gravelly loamy sand lacking discernable ped structure and overlies moderately weathered sandstone at a depth of about 90 cm. The

substratum is mottled resulting from segregation and oxidation of iron compounds.

Infiltration is moderate and permeability is moderate to 55 cm, rapid from 55 to 90 cm and very slow below 90 cm. The effective rooting depth is about 90 cm. Surfaces are slightly to moderately eroded in interspaces between shrub canopies resulting in a slightly hummocky relief. The surface horizon described for the typic pedon is absent in shrub corridors.

Common mottles in the layers below 55 cm indicate that substrata are wet for significant periods of the growing season. Characteristics appear favorable for burrowing rodents above this depth.

B.1.2.17 (61a) Coarse-loamy, Typic Ustifluvent (0-2% Slope). This map unit is described for an alluvial terrace of grid WR-2. Although no inclusions were identified, a degree of heterogeneity in textural stratification is probable.

This soil is very deep and well drained. The surface horizon is comprised of alluvial debris including litter and fecal material mixed with coarse sand. This material was deposited by flood waters emanating from an upland drainage canyon in the spring of 1983. Subtending layers to a depth of about 100 cm are distinctly stratified loams, silt loams, and very fine sandy loams mixed with variable amounts of organic debris. Structural development and consistence of these stratified layers varies from weak to moderate structure and loose to slightly hard consistence. Materials below 100 cm to over 150 cm is loamy coarse sand with small volumes of rounded gravel and loose consistence. The normal ground water level is about 200 cm below the surface.

Infiltration and permeability are moderate to moderately rapid and runoff is very slow. The effective rooting depth is about 150 cm. Surfaces are uneroded and receive periodic deposition from floods emanating from the upslope drainage canyon.

Seasonal flooding and periodic depositional events may be limiting factors to burrowing rodent populations. Highly stratified horizons, loose consistence and unstable materials are additional potentially limiting characteristics.

B.1.2.18 (62a) Sandy, Typic Ustifluvent (1-3% Slope). This map unit is described for areas of grid WR-2 which recieve periodic deposition of coarse grained alluvial material. The map unit may be further delineated into two phases: 1) areas where deposition of sediments occurs on an annual basis (62a'); and 2) areas where desposition of sediments occurs at less frequent intervals (62a). Soil characteristics of the two phases are essentially very similar although surface characteristics and associated floristic components show marked divergence.

Soils of this map unit are very deep and excessively drained. Materials are loose sand and loamy sand to a depth of over 150 cm.

Infiltration and permeability are rapid to very rapid and runoff is very slow. The effective rooting depth is about 150 cm. Surfaces are apparently uneroded although materials may be redistributed to some extent by both aeolean and fluvial forces.

Very loose consistence, absence of soil structure and seasonal deposition of mineral material are probable limitations to habitation by burrowing rodents.

B.1.2.19 (63a) Coarse-loamy/Fine-loamy, Typic Ustifluvent (0-2% Slope)

This map unit is described for the alluvial bench comprising the major fraction of grid WR-1 and WR-4. Although no inclusions were identified a degree of heterogeneity in textural stratification with depth is probable.

The named component is very deep and moderately well drained. The surface layer is loam texture with moderately strong ped structure, soft consistence and is about 7 cm thick. The subtending stratum is 23 cm thick and silt loam texture. Material to 55 cm is loose loamy sand texture lacking discernable ped structure. Subtending material to 90 cm depth is silt clay loam texture with moderately strong platy structure and inclusive of relatively high amounts of organic material. This horizon appears to be remnant of a swampy backwash. Substratum to a depth of over 150 cm is sandy loam texture with no discernable ped structure and loose consistence. Materials between 120 and 150 cm are mottled as a result of fluctuation in ground water level. The normal level of ground water is about 175 cm below the surface.

Infiltration is moderate and permeability is moderate to moderately rapid to 55 cm and moderately slow to slow between 55 and 90 cm. Runoff is slow. Surfaces are uneroded and the relief is smooth and even. The effective rooting depth is 120 to 150 cm.

The fine textured horizon at 55 cm depth is somewhat limiting to the downward percolation of water. As a result this soil remains moist for longer durations. Loose consistence of the strata immediately above the fine-textured layer may also be limiting to burrowing rodent populations.

B.1.2.20 (71a) Sandy/fine-loamy/sandy Aquic Ustifluvent (0-3% Slope) This map unit is described for a lower terrace position of grid WR-4. No inclusions of contrasting soils were observed.

This soil is very deep and somewhat poorly drained. The surface layer is loamy sand texture and is about 10 cm thick. The subtending horizon is loose loamy sand texture and is about 20 cm thick. A clay loam and a fine silt loam stratum totaling 40 cm thick subtend the surface horizon. These fine strata are remnant of a swampy backwash upon which sandy alluvium has since been deposited. Subtending materials are loose sand and loamy sand to a depth below 150 cm. The ground water level fluctuates between 70 and 130 cm as evidenced by distinct and prominent mottles resulting from segregation and subsequent oxidation/reduction of iron compounds.

Infiltration is rapid and permeability is rapid to 30 cm, moderately slow between 30 and 70 cm and rapid below 70 cm. Runoff is moderately slow. Surfaces are uneroded and subject to infrequent depositional events both from floods originating from uplands and overflow of the White River from its normal banks. Soils are moist below a depth of 30 cm for significant periods of the growing season.

Loose consistence of surface materials and moist substrata are potentially limiting factors to burrowing rodent populations.

B.1.2.21 (72a) Sandy, Aquic Ustifluvent (0-2% Slope) This map unit is described for low bank terraces adjacent and parallel to the White River in grids WR-1 and WR-2. Two surface phases of the map unit are described: 1) surfaces highly eroded by recent fluventic processes (72a') and 2) surfaces

not recently eroded by fluventic processes (72a). No inclusions of contrasting soil types were observed.

This soil is deep and somewhat poorly drained. Materials are loose loamy sand to depths below 120 cm. The ground water level is about 100 cm during peak spring runoff.

Infiltration and permeability are rapid and runoff is very slow. The effective rooting depth is about 100 cm. Soil materials are deposited by infrequent overflow of the White River from its channel during flood events.

Parameters potentially limiting to burrowing rodent populations are very loose consistence of soil materials, wet substrata and periodic fluventic disturbance.

B.2 SOIL TAXA

Soil taxa are phases of soil families. Typic pedons are described for the dominant component of each map unit.

B.2.1 (11Kbc) Type Description

Family Taxa: Loamy-skeletal, mixed, mesic, Lithic Torriorthent.

Typic Pedon: WS-4-3.

A1 (0-6 cm) Pale brown (10YR6/3) loamy sand, dark grayish brown (10YR4/2) moist; weak fine granular structure; soft, loose, nonsticky and nonplastic; noncalcareous; few very fine roots; no pores; clear smooth boundary.

AC (6-23 cm) Pale brown (10YR6/3) sandy loam, brown (10YR4/3) moist; few thin clay skins on ped faces; weak medium subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; slightly calcareous; few very fine, fine and medium roots; few very fine pores; clear smooth boundary.

C1kr (23-30cm) Light yellowish brown (10YR6/4) extremely channery sandy loam, brown (10YR5/3) moist; 65 percent channer; single grain; loose, loose, nonsticky and nonplastic; moderately calcareous; thin carbonate pendants on

coarse-fragments; few very fine, few fine and common medium roots; no pores; abrupt broken boundary.

R (30+ cm) Very fractured, hard, sandstone bedrock; fractured both horizontally into laminar planes and vertically into channer and flagstone.

B.2.2 (11Kbc) Type Description

Family Classification: Loamy-skeletal, mixed, mesic, Lithic Torriorthent.

Typic Pedon: WG-1-1.

A1 (0-10 cm) Yellowish brown (10YR5/4) sandy loam, dark yellowish brown (10YR4/4) moist; weak medium granular structure; soft, loose, nonsticky and nonplastic; moderately calcareous; few very fine and fine roots; no pores; gradual smooth boundary.

C1k (10-36 cm) Yellowish brown (10YR5/4) very channery sandy loam, dark yellowish brown (10YR4/3) moist; 55 percent channer and flagstone; single grain; loose, loose, nonsticky and nonplastic; strongly calcareous; carbonate pendants on rock fragments; few very fine and fine roots; no pores; gradual smooth boundary.

C2kr (36-50 cm) Light yellowish brown (10YR6/4) extremely channery very fine sandy loam, yellowish brown (10YR5/4) moist; 65 percent soft channer and flagstone; loose, loose, nonsticky and nonplastic; strongly calcareous; few very fine and fine roots; no pores; clear smooth boundary.

R (50+ cm) Fractured sandstone bedrock.

B.2.3 (12Kd) Type Description

Family Classification: Loamy-skeletal, mixed, mesic, Lithic Torriorthent.

Typic Pedon: WS-1-4.

A1 (0-10 cm) Light yellowish brown (10YR6/4) sandy loam, brown (10YR5/3) moist; 10 percent channer; weak fine granular structure; soft, loose, nonsticky and nonplastic; stongly calcareous; common very fine and few fine roots; no pores; clear smooth boundary.

C1 (10-30 cm) Light yellowish brown (10YR6/4) extremely channery sandy loam, brown (10YR5/3) moist; 75 percent channer; single grain; loose, loose, nonsticky and nonplastic; strongly calcareous; few very fine roots; no pores; diffuse boundary.

R Very fractured and laminar soft shale bedrock.

B.2.4 (13Xde and 14Xc) Type Description

Family Classification: Fragmental, mixed, mesic, Lithic Torriorthent.

Typic Pedon: WJ-5-2.

C1 (0-15 cm) Pale brown (10YR6/3) extremely channery sandy loam, brown (10YR5/3) moist; 70 percent channer; single grain; loose, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated and as pendants on coarse-fragments; few very fine and fine roots; no pores; diffuse boundary.

R (15+ cm) Hard, fractured sandstone bedrock.

B.2.5 (21bc) Type Description

Family Classification: Coarse-loamy, mixed, mesic, Typic Torriorthent.

Typic Pedon: WS-1-1.

A1 (0-8 cm) Pale brown (10YR6/3) sandy loam, yellowish brown (10YR5/4) moist; 5 percent very fine angular gravel; weak medium platy structure; soft, very friable, nonsticky and nonplastic; slightly calcareous; common very fine and few fine roots; no pores; clear smooth boundary.

C1 (8-45 cm) Light yellowish brown (10YR6/4) sandy loam, yellowish brown (10YR5/4) moist; 5 percent very fine angular gravel; loose, loose, nonsticky and nonplastic; slightly calcareous; few very fine, fine and medium roots; few very fine pores; clear wavy boundary.

C2 (45-90 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, yellowish brown (10YR5/4) moist; 25 percent very fine angular gravel; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; slightly calcareous; few very fine roots; few very fine pores; abrupt smooth boundary.

R Hard, slightly fractured shale bedrock.

B.2.6 (22b) Type Description

Family Classification: Coarse-loamy, mixed, mesic, Typic Torriorthent.

Typic Pedon: WS-1-3.

A1 (0-10 cm) Light brownish gray (10YR6/2) sandy loam, dark grayish brown (10YR4/2) moist; weak medium granular; soft, loose, nonsticky and nonplastic; slightly calcareous; many very fine roots; no pores; clear smooth boundary.

C1 (10-45 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, brown (10YR4/3) moist; 15 percent fine angular gravel; massive; loose, loose, nonsticky and nonplastic; slightly calcareous; many very fine and few fine roots; few very fine pores; diffuse boundary.

C2 (45-80 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, brown (10YR5/3) moist; 10 percent angular gravel; massive; loose, loose, nonsticky and nonplastic; slightly calcareous; common very fine and few fine roots; few very fine pores; diffuse boundary.

C3 (80-110 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, brown (10YR5/3) moist; 15 percent fine angular gravel; weak fine subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; slightly calcareous; few very fine roots; no pores; diffuse boundary.

C4 (110-140 cm) Pale brown (10YR6/3) slightly gravelly sandy loam, brown (10YR5/3) moist; 5 percent angular gravel; weak fine subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; slightly calcareous; few very fine roots; no pores; abrupt smooth boundary.

R (140+ cm) Slightly weathered, laminarly fractured shale bedrock.

B.2.7 (22Kbc) Type Description

Family Classification: Loamy-skeletal, mixed, mesic, Typic Torriorthent.

Typic Pedon: WG-3-1.

A1 (0-5 cm) Light yellowish brown (10YR6/4) sandy loam, grayish brown (10YR5/2) moist; 10 percent subangular gravel; weak medium granular structure; soft, loose, nonsticky and nonplastic; slightly calcareous; common very fine and few fine roots; no pores; clear smooth boundary.

AC (5-19 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, grayish brown (10YR5/2) moist; 30 percent subangular gravel; weak fine subangular blocky structure; soft, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated; common very fine and few fine roots; no pores; clear smooth boundary.

C1 (19-33 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, brown (10YR5/3) moist; 35 percent subangular gravel and cobble; weak fine subangular blocky structure; soft loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated; few very fine and fine roots; no pores; gradual smooth boundary.

C2 (33-56 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, brown (10YR5/3) moist; 35 percent fine gravel; weak fine subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated; few very fine and fine roots; no pores; diffuse boundary.

C3 (110-150 cm) Light yellowish brown (10YR6/4) gravelly sandy loam, yellowish brown (10YR5/4) moist; 15 percent fine gravel; weak medium subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; moderately calcareous; lime disseminated; few very fine and fine roots; no pores.

B.2.8 (31a) Type Description

Family Taxa: Sandy, mixed, mesic, Typic Torrifluvent.

Typic Pedon: WG-3-2.

A1 (0-6 cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; weak fine granular structure; loose, loose, nonsticky and nonplastic; slightly calcareous; common very fine roots; no pores; clear smooth boundary.

C1 (6-25 cm) Light yellowish brown (10YR6/4) loamy sand, brown (10YR5/3) moist; massive; loose, loose, nonsticky

and nonplastic; moderately calcareous; lime is disseminated; few very fine roots; no pores; diffuse boundary.

C2 (25-65 cm) Light yellowish brown (10YR6/4) loamy sand, brown (10YR5/3) moist; massive; loose, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated; no roots; few fine pores; diffuse boundary.

C3 (65-110+ cm) Light yellowish brown (10YR6/4) loamy sand, brown (10YR5/3) moist; massive; loose, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated; no roots; no pores.

B.2.9 (32a) Type Description

Family Classification: Sandy/coarse-loamy, mixed mesic Typic Torriorthent.

Typic Pedon: WG-1-2.

A1 (0-10 cm) Yellowish brown (10YR5/4) sandy loam, brown (10YR5/3) moist; weak coarse granular structure parting to single grain; soft, loose, nonsticky and nonplastic; slightly calcareous; common very fine roots; no pores; clear smooth boundary.

C1 (10-20 cm) Yellowish brown (10YR5/4) loamy sand, brown (10YR5/3) moist; weak medium subangular structure; slightly hard, very friable, nonsticky and nonplastic; moderately calcareous; common very fine roots; no pores; clear smooth boundary.

C2 (20-45 cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; massive; loose, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated; common very fine roots; no pores; clear smooth boundary.

IIC3k (45-105 cm) Light yellowish brown (10YR6/4) very fine sandy loam, brown (10YR5/3) moist; 5 percent subangular gravel; weak medium subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; moderately calcareous; lime is disseminated and as pendants on coarse fragments; common very fine roots; no pores; gradual smooth boundary.

IIC4k (105-150 cm) Light yellowish brown (10YR6/4) channery sandy loam, brown (10YR5/3) moist; 20 percent channer; massive; loose, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated and as

pendants on coarse fragments; few very fine and fine roots; no pores.

B.2.10 (33ab) Type Description

Family Classification: Coarse-loamy, mixed, mesic, Typic Torrifluvent.

Typic Pedon: WG-1-3.

A1 (0-10 cm) Light brownish gray (10YR6/2) sandy loam, brown (10YR5/3) moist; 10 percent subangular gravel; weak medium subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; slightly calcareous; common very fine and few fine roots; no pores; clear smooth boundary.

AC (10-30 cm) Light brownish gray (10YR6/2) sandy loam, brown (10YR5/3) moist; moderate medium subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; slightly calcareous; common very fine and few fine roots; no pores; clear smooth boundary.

C1k (30-100 cm) Pale brown (10YR6/3) sandy loam, brown (10YR5/3) moist; 5 percent subangular gravel; weak fine subangular structure; soft, soft, nonsticky and nonplastic; moderately calcareous; few thin pendants on coarse fragments; few very fine, fine and medium roots; few fine pores; gradual smooth boundary.

C2k (100-150 cm) Pale brown (10YR6/3) gravelly sandy loam, brown (10YR5/3) moist; 35 percent gravel and channer; single grain; loose, loose, nonsticky and nonplastic; moderately calcareous; common thin pendants on coarse fragments; few very fine and fine roots; no pores.

B.2.11 (41b) Type Description

Family Classification: Fine-loamy, mixed, mesic, Typic Natriargid.

Typic Pedon: WS-4-2.

A1 (0-10 cm) Light yellowish brown (10YR6/4) very fine sandy loam, dark yellowish brown (10YR4/4) moist; weak medium granular structure; soft, loose, nonsticky and slightly plastic; slightly calcareous; few very fine roots; no pores; clear smooth boundary.

Bt (10-25 cm) Light brown (7.5YR6/4) loam, brown (7.5YR4/4) moist; common moderately thick clay skins on ped faces; moderate medium prismatic parting to weak medium subangular blocky structure; very hard, firm, sticky and very plastic; moderately calcareous; lime is disseminated; few very fine and fine roots; few fine pores; diffuse boundary;

BC (25-50 cm) Light brown (7.5YR6/4) loam, strong brown (7.5YR4/6) moist; weak medium prismatic parting to moderate fine subangular blocky structure; hard, friable, slightly sticky and plastic; moderately calcareous; lime is disseminated; few very fine and fine roots; gradual smooth boundary.

C2z (50-105 cm) Pink (7.5YR7/4) silt loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; moderately calcareous; crystaline salts in pockets 1 to 3 mm in diameter; few very fine roots; no pores; clear smooth boundary.

IIC3k (105-145 cm) Light olive brown (2.5Y5/6) sandy loam, light olive brown (2.5Y5/4) moist; common moderate prominant mottles (7.5YR5/6); single grain; loose, loose, nonsticky and nonplastic; moderately calcareous; lime is disseminated and in few cemented fragments; no roots; no pores; clear smooth boundary.

R (145+ cm) Moderately weathered, soft sandstone.

B.2.12 (51b) Type Description

Family Classification: Coarse-loamy, mixed, mesic, Typic Camborthid.

Typic Pedon: WS-4-1.

A1 (0-12 cm) Yellowish brown (10YR5/4) sandy loam, dark yellowish brown (10YR4/4) moist; weak medium granular structure; soft, loose, nonsticky and nonplastic; slightly calcareous; few very fine roots; no pores; gradual smooth boundary.

B (12-37 cm) Yellowish brown (10YR5/6) sandy loam, dark yellowish brown (10YR5/4) moist; moderate medium subangular blocky structure; slightly hard, loose, nonsticky and nonplastic; slightly calcareous; few very fine, common fine and few medium roots; few very fine pores; gradual smooth boundary.

C1z (37-55 cm) Very pale brown (10YR7/4) sandy loam, light yellowish brown (10YR6/4) moist; moderate fine subangular blocky structure; hard, friable, nonsticky and noplastic; moderately calcareous; common gypsum coatings; few very fine and fine roots; no pores; gradual smooth boundary.

C2 (55-90 cm) Very pale brown (10YR7/4) sandy loam, yellowish brown (10YR5/4) moist; common medium prominant mottles (7.5YR5/6); 10 percent soft gravel; massive; loose, loose, nonsticky and nonplastic; few very fine and fine roots; no pores; clear smooth boundary.

R Soft, weathered sandstone; relatively unfractured.

B.2.13 (61a) Type Description

Family Classification: Coarse-loamy, mixed, mesic, Typic Ustifluvent.

Typic Pedon: WR-2-2.

O&C (0-5 cm) Light yellowish brown (10YR6/4)sandy loam, brown (10YR5/3) moist; 25 percent alluvial fecal material; laminar structure; recent deposition; loose, loose, nonsticky and nonplastic; slightly calcareous; few fine, very fine and medium roots; no pores; clear smooth boundary.

A1 (5-20 cm) Brown (10YR5/3) silt loam, dark grayish brown (10YR4/2) moist; moderate fine angular blocky structure; slightly hard, friable, nonsticky and nonplastic; slightly calcareous; few very fine and course, common fine and medium roots, no pores; clear smooth boundary.

IIA&C (20-60 cm) Light yellowish brown (10YR6/4) loam, brown (10YR5/3) moist; few fine distinct mottles; moderate very fine platy structure; soft, very friable, nonsticky and nonplastic; slightly calcareous; few very fine, fine and medium roots; few fine pores; abrupt smooth boundary.

IIC (60-98 cm) Light yellowish brown (10YR6/4) very fine sandy loam, brown (10YR5/3) moist; weak coarse subangular blocky structure; soft, loose, nonsticky and nonplastic; slightly calcareous; few very fine and fine roots; no pores; abrupt smooth boundary;

IIIA (98-102 cm) Brown (10YR5/3) silt loam, dark grayish brown (10YR4/2) moist; weak very fine platy structure; slightly hard, firm, slightly sticky and slightly

plastic; slightly calcareous; few fine roots; no pores; abrupt smooth boundary.

IIIC (102-150+ cm) Yellowish brown (10YR5/3) slightly gravelly loamy coarse sand, brown (10YR4/3) moist; single grain; loose, loose, nonsticky and nonplastic; slightly calcareous; no roots; no pores.

B.2.14 (62a) Type Description

Family Classification: Sandy, mixed, mesic, Typic Ustifluvent.

Typic Pedon: WR-2-4.

C (0-130 cm) Light yellowish brown (10YR6/4) loamy sand stratified with layers of coarse sand, brown (10YR5/4) moist; single grain surface and massive in substrata; loose, loose, nonsticky and nonplastic; few, fine, medium, and coarse roots; no pores.

B.2.15 (63a) Type Description

Family Classification: Coarse-loamy/fine-loamy, mixed, mesic, Typic Ustifluvent.

Typic Pedon: WR-4-2.

A1 (0-7 cm) Brown (10YR5/3) loam, dark brown (10YR3/3) moist; moderate fine granular structure; soft, very friable, nonsticky and nonplastic; slightly calcareous; few very fine and medium, common fine roots; no pores; clear smooth boundary.

AC (7-30 cm) Pale brown (10YR6/3) silt loam, brown (10YR5/3) moist; weak coarse granular structure; soft very friable slightly sticky and slightly plastic; moderately calcareous; few very fine and medium, common fine roots; no pores; clear smooth boundary.

C1 (30-55 cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; massive; loose, loose, nonsticky and nonplastic; moderately calcareous; few very fine and fine roots; no pores; clear smooth boundary.

IIA&C (55-90 cm) Light yellowish brown (10YR6/4) silty clay loam, dark brown (10YR4/3) moist; moderate medium platy structure; slightly hard, firm, sticky and plastic; moderately calcareous; few very fine and fine roots; no pores; abrupt smooth boundary.

IIIC2 (90-120 cm) Light yellowish brown (10YR6/4) sandy loam, yellowish brown (10YR5/4) moist; single grain; loose, loose, nonsticky and nonplastic; moderately calcareous; few very fine roots; no pores; diffuse boundary.

IIIC4 (120-150 cm) Pale brown (10YR6/3) sandy loam, brown (10YR5/3) moist; common medium prominant mottles (7.5YR5/6); massive; slightly hard, very friable, nonsticky and nonplastic; moderately calcareous; no roots; no pores.

B.2.16 (71a) Type Description

Family Classification: Sandy/fine-loamy/sandy, mixed, mesic, Aquic Ustifluvent.

Typic Pedon: WR-4-1.

A1 (0-10 cm) Light yellowish brown (10YR6/4) loamy sand, brown (10YR5/3) moist; moderate coarse angular blocky structure; slightly hard, friable, nonsticky and nonplastic; slightly calcareous; few very fine and fine roots; no pores; clear smooth boundary.

C1 (10-30 cm) Light yellowish brown (10YR6/4) loamy sand, brown (10YR5/3) moist; single grain; loose, loose, nonsticky and nonplastic; moderately calcareous; few very fine and fine roots; no pores; abrupt smooth boundary.

IIA (30-44 cm) Pale brown (10YR6/3) clay loam, brown (10YR5/3) moist; moderate very fine angular blocky structure; common very thin clay skins on ped faces; slightly hard, firm sticky and plastic; slightly calcareous; few very fine and fine roots; no pores; clear smooth boundary.

IIB (44-70 cm) Light yellowish brown (10YR6/4) silt loam, brown (10YR5/3) moist; weak coarse prismatic parting to weak medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; slightly calcareous; few very fine and fine roots; common very fine pores; abrupt smooth boundary.

IIC2 (70-130 cm) Light yellowish brown (10YR6/4) sand, yellowish brown (10YR5/4) moist; few fine distinct mottles (7.5YR5/6); single grain; loose, loose, nonsticky and nonplastic; noncalcareous; few fine and medium roots; no pores; diffuse boundary.

IIC3 (130-150+ cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; common medium distinct mottles (7.5YR5/6); single grain; loose, loose, nonsticky and nonplastic; noncalcareous; few fine and medium roots; no pores.

B.2.17 (72a) Type Description

Family Classification: Sandy, mixed, mesic, Aquic Ustifluvent.

Typic Pedon: WR-2-1.

C1 (0-100 cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; single, grain; loose, loose, nonsticky and nonplastic; slightly calcareous; few very fine, fine and medium roots; no pores; gradual boundary.

C2 (100-120 cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; common medium prominant mottles (7.5YR5/6); single grain; loose, loose, nonsticky and nonplastic; slightly calcareous, no roots; no pores; gradual boundary.

C3 (120-150+ cm) Light yellowish brown (10YR6/4) loamy sand, yellowish brown (10YR5/4) moist; many medium prominant mottles (7.5YR5/6); single grain; loose, loose, nonsticky and nonplastic; noncalcareous; no roots; no pores.

B.3 LITERATURE CITED

USDA-SCS. 1975. Soil Taxonomy - A Basic System of Soil Classification for Making and Interpretting Soil Surveys, USDA Handbook No. 436. U.S. Government Printing Office. Washington D.C. 503 pp.

USDA-SCS. 1981. Draft Soil Survey Manual (revised). U.S. Government Printing Office. Washington D.C.

ECOSYSTEM ANALYSIS

8.0 ECOSYSTEM ANALYSIS

8.1 INTRODUCTION

The White River Shale Oil Corporation in its environmental monitoring program is mandated to fulfill the guidelines outlined by the Oil Shale Project Office (OPO). These guidelines (OSO 1979) include:

- Describe existing environmental conditions.
- Identify candidate potential parameters to monitor during the initial development phase.
- Select potential parameters to monitor based on likelihood of impact, degree of impact, importance, legal requirements, measurability, interpretability and cost effectiveness.
- Design statistical procedures for detecting and evaluating degree of impact.
- Develop a quality assurance program.
- Build into a computer program appropriate threshold values for specific parameters.
- Design a contingency plan.

Publication of an Environmental Monitoring Manual (EMM) in 1982 (WRSOC 1982) established the framework for meeting these OSO guidelines. Within this document, WRSOC established overall program goals as well as goals for each of the five major environmental disciplines; air resources, vegetation,

aquatic biology, terrestrial fauna and water resources. WRSOC recognized the need for integrating the information generated within these five disciplines and maintaining focus for achieving the OSO guidelines. It was also recognized that the program must be flexible, allowing change and refinement as knowledge about the tract ecosystem and potential impacts grows. Ecosystem Analysis was both the philosophical and contractual mechanism chosen to accomplish this task. The goals of these programs are summarized in Table 8.1-1.

WRSOC recognized further that developing the ability to document an impact as well as its source could be extremely expensive if some organizing principal was not found which could simplify the selection and correct statistical interpretation of monitoring parameters. To accomplish this, the Ecosystem Approach was taken. This approach recognizes that the biological system components respond to the abiotic driving variables (Figure 8.1-1) and that an effect upon one part of the ecosystem may well be exhibited by changes in several related system components. This conceptual view thus includes the concept of a pathway or the transmission of an environmental impact through dependent system components.

The environmental disciplines within the WRSOC environmental program address the major biotic and abiotic components of the ecosystem while Ecosystem Analysis attempts to interrelate all factors and recommend program refinements to enhance sensitivity for impact detection. The organization of this environmental program reflects the conceptual model of an ecosystem (Figure 8.1-2).

Table 8.1-1. Summary of program goals for all aspects of the WRSOC environmental monitoring program.

WRSP OVERALL MONITORING PROGRAM GOALS

- Allow assessment of changes occurring in the physical and biological characteristics of the tracts as a result of development and operation.
- Guide analysis of cause and effect leading to appropriate mitigation planning.
- Guide and assess the effectiveness of impact mitigation and reclamation.

AIR RESOURCE PROGRAM GOALS

- Quantitatively determine air quality impacts of various levels of oil shale development and operation on Tracts Ua and Ub.
- Demonstrate that impacts of the air contaminants emitted by WRSP are in compliance with State and Federal Standards.
- Observe the long-term evolution of regional air quality.
- Monitor the meteorological environment to provide additional data for future modeling efforts and events that might affect air quality.

VEGETATION PROGRAM GOALS

- Document existing vegetation conditions during and after various stages of development, including the range of variation exhibited temporally and geographically.
- Quantify plant responses to environmental impacts created by development, thereby allowing comparisons of plant responses in areas of little or no impact with those in areas of relatively high impact.
- Measure success of reclamation techniques on the processed shale disposal area and other areas that may be disturbed.

AQUATIC BIOLOGY PROGRAM GOALS

- Gather data which describes the aquatic ecosystem in sufficient detail to allow assessment of natural or project-related change.
- Organize data collection and analysis using a conceptual view of the ecosystem to determine the cause or pathway of these changes.
- Assess the effectiveness of mitigation and reclamation measures.
- Contribute to ongoing studies concerning endangered fish species.

TERRESTRIAL FAUNA PROGRAM GOALS

- Determine if there is a departure from "normal", defined as ambient conditions during the seven-year baseline period.
- Discover if this departure is caused by project activities or if it is related to natural environmental changes.
- Evaluate the success of reclamation efforts in terms of returning disturbed areas to their original carrying capacity.
- Provide input to reclamation effort concerning herbivore populations and mitigation approaches.

WATER RESOURCE PROGRAM GOALS

- Demonstrate that project impacts comply with federal, state and local regulations.
- Demonstrate capibility of differentiating between natural and project-related perturbations by use of control-treatment stations.
- Gather information which can be statistically and graphically analyzed to determine variations from baseline conditions.
- Determine effectiveness of mitigation measures.
- Provide hydrometeorological input in the design of project impoundment structures.

ECOSYSTEM ANALYSIS PROGRAM GOALS

- Integrate data from each discipline into a holistic picture of the environment.
- Analyze for and identify ecologically meaningful relationships within and among the disciplines which provide information concerning impact pathways.
- Provide recommendations concerning changes in sampling methodology which would reduce the variability and increase the sensitivity of important parameters and relationships at the lowest cost to WRSOC.
- Develop efficient computer software to perform inter- and intra-disciplinary data analysis.
- Centralize all environmental data under a uniform library and cataloging system.

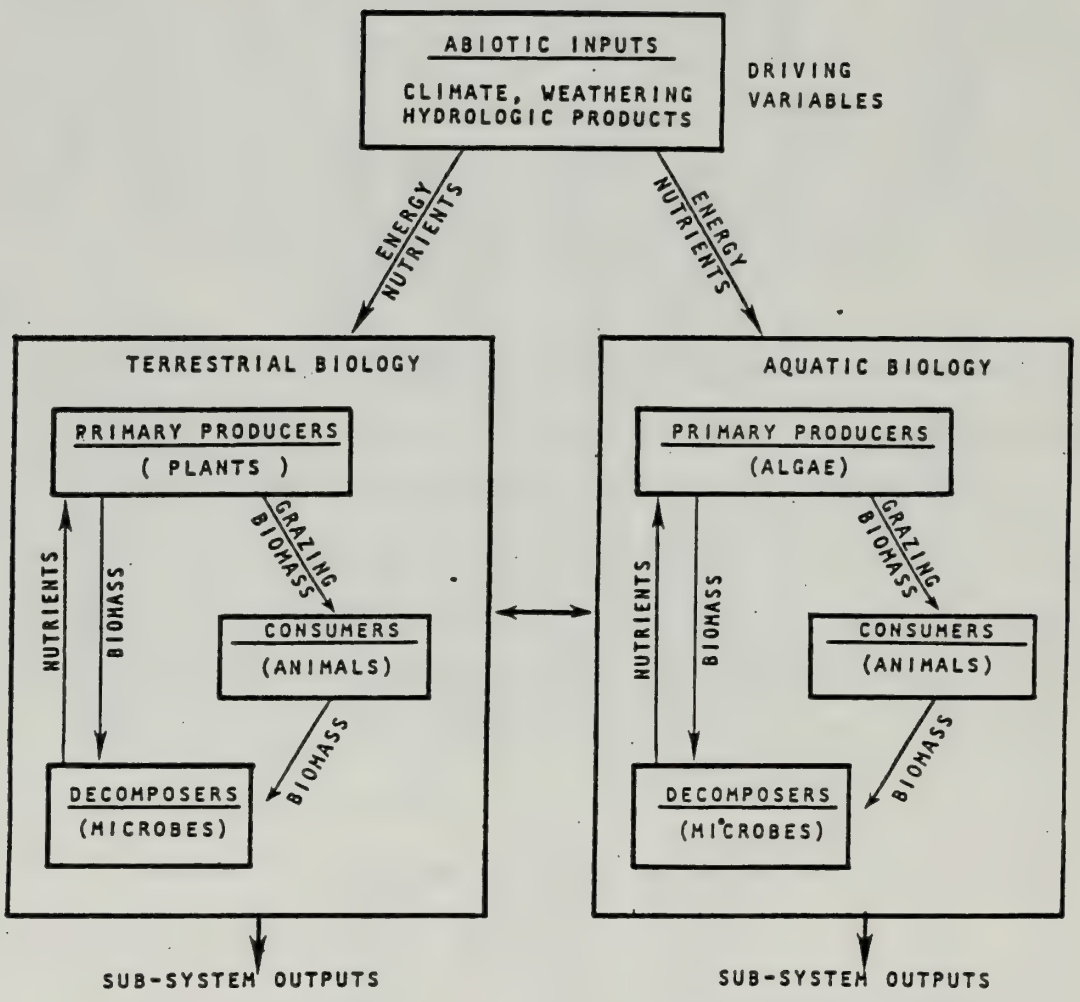

Figure 8.1-1. Conceptual diagram of ecosystem organization.

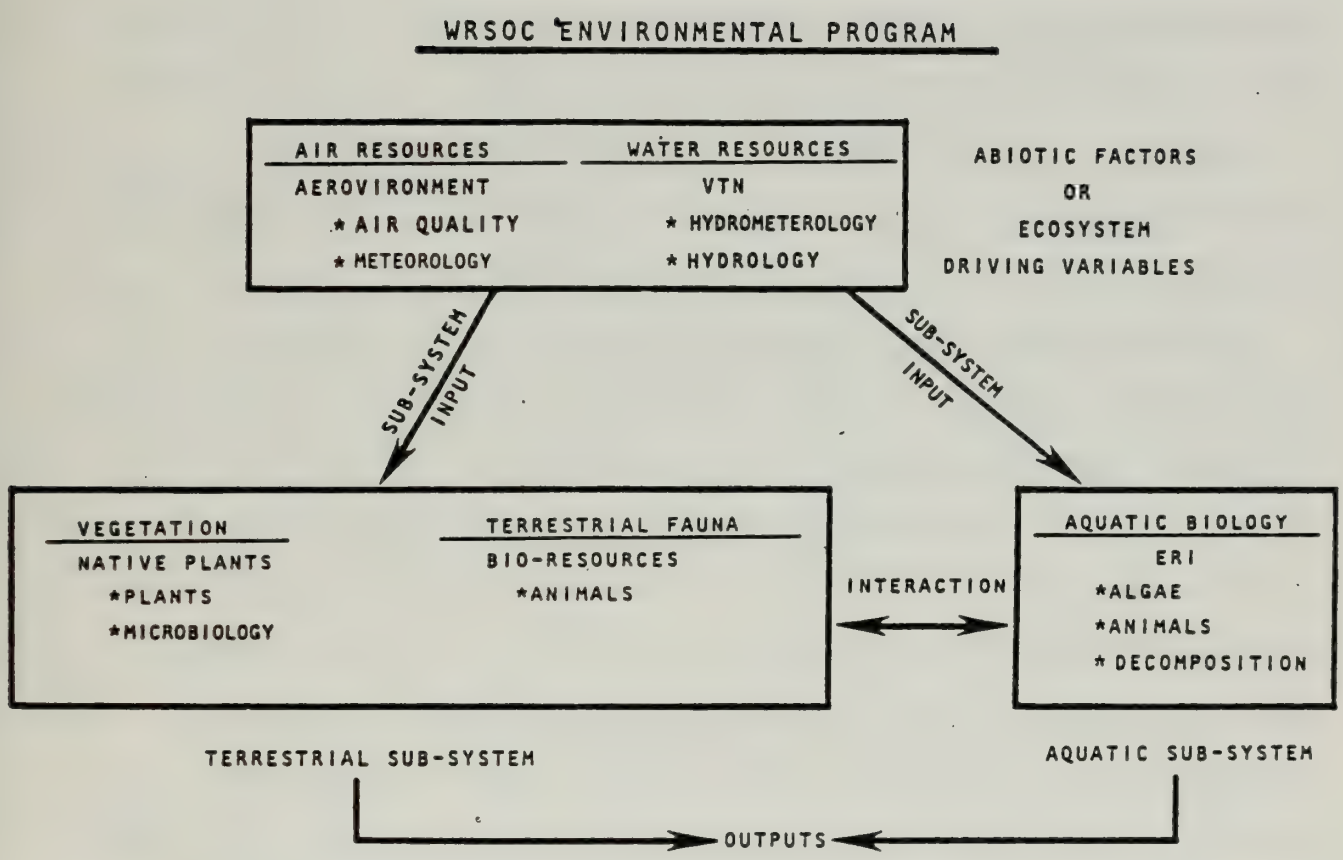

Figure 8.1-2. Diagram of WRSOC environmental program organization.

Ecosystem Analysis, which was initiated in 1983, is conducted under the direction of Ecosystem Research Institute of Logan, Utah. This program involves an understanding of processes affecting environmental parameters, determination of relationships between various parameters in the environment, and identification of potential effects of development-related pollutants on the ecosystem. An understanding of cause and effect in ecosystem relationships will be useful for distinguishing effects of development from variability inherent to natural ecosystems and in pathway analysis.

The White River Shale Oil Corporation has been conducting an environmental monitoring program in five major disciplines since 1974. These include air resources, vegetation, aquatic biology, terrestrial fauna, and water resources. The data collected during those years constitutes an excellent baseline data base and one of the most thorough descriptions of an area ever assembled. However, the continuation of collection of largely descriptive data may not be necessary if true quantitative monitoring parameters related to specific types of project related impacts can be identified. The 1983 Ecosystem Analysis program began addressing this issue through ongoing internal program review and analysis. The objectives considered in this report are:

1. Describe the Ecosystem Analysis program and its accomplishments during 1983.

2. Demonstrate the operation of Ecosystem Analysis by developing cause/effect relationships across disciplines.

3. Evaluate data collection within disciplines as related to overall program goals.

The ecosystem level analysis conducted during 1983 and addressed in this report focused upon the development of relationships between climatic, pedogenic (soil) and floristic parameters. It should be noted that while analyses and comments in this report apply to climatic, pedogenic and floristic parameters, similar interpretations may apply to all disciplines. The scope of this analysis was constrained by time and funds so that all disciplines and parameters could not be addressed. The principles addressed are the same, however. Detailed tasks are described in Section 8.3 Program Description. A summary of 1983 accomplishments follows.

8.2 SUMMARY

This summary addresses the major tasks accomplished by Ecosystem Analysis during 1983. These include: development of a data library and cataloging system; program review; precipitation and evaporation data analyses; and an evaluation of vegetation parameters for monitoring.

8.2.1 Development of a Data Library and Cataloging System

During 1983, data tapes from each of the five environmental disciplines including Air Resources, Vegetation, Aquatic Biology, Terrestrial Fauna and Water Resources were documented and delivered to WRSOC for the creation of a single, active data base library for the WRSP. Duplicate tapes from each discipline were submitted to the Oil Shale Project Office (OSPO) for their records. These tapes contain most of the data collected on Tracts Ua and Ub

from 1974 to 1982.

The data tapes were placed on active disk storage on the VAX-11 computer system at Utah State University. Additional backup tapes of the data on disk were also created. The data tapes and documentation are maintained at the ERI offices in Logan, Utah.

The MONITOR program (WRSOC 1982) for data analysis was updated in language compatible with the VAX-11 system and placed on line. It was set up to work in conjunction with the data library. MONITOR will be activated following the verification of suitable monitoring parameters and relationships. MONITOR will operate on selected historical data, making appropriate statistical comparisons as current data is added.

A cataloging system is being developed for the data library. The purpose of the cataloging system is to provide information on what data were collected, when each type of data was collected, where each type of data was collected, and what computer files and tapes contain the data of interest. A sample library coding sheet is included as an example (Figure 8.2-1). To date, data files from 1974 to 1982 for the air resources, terrestrial fauna and vegetation programs have been completely catalogued. Aquatic biology and water resources data files are in the process of being catalogued.

The cataloging system will consist of three major items: 1) A document which allows the user to understand and access the system; 2) a computerized catalog summarizing important information about each data type; and 3) informational software which will allow the user easy access to the data and data management software. This software is scheduled for completion by May, 1984.

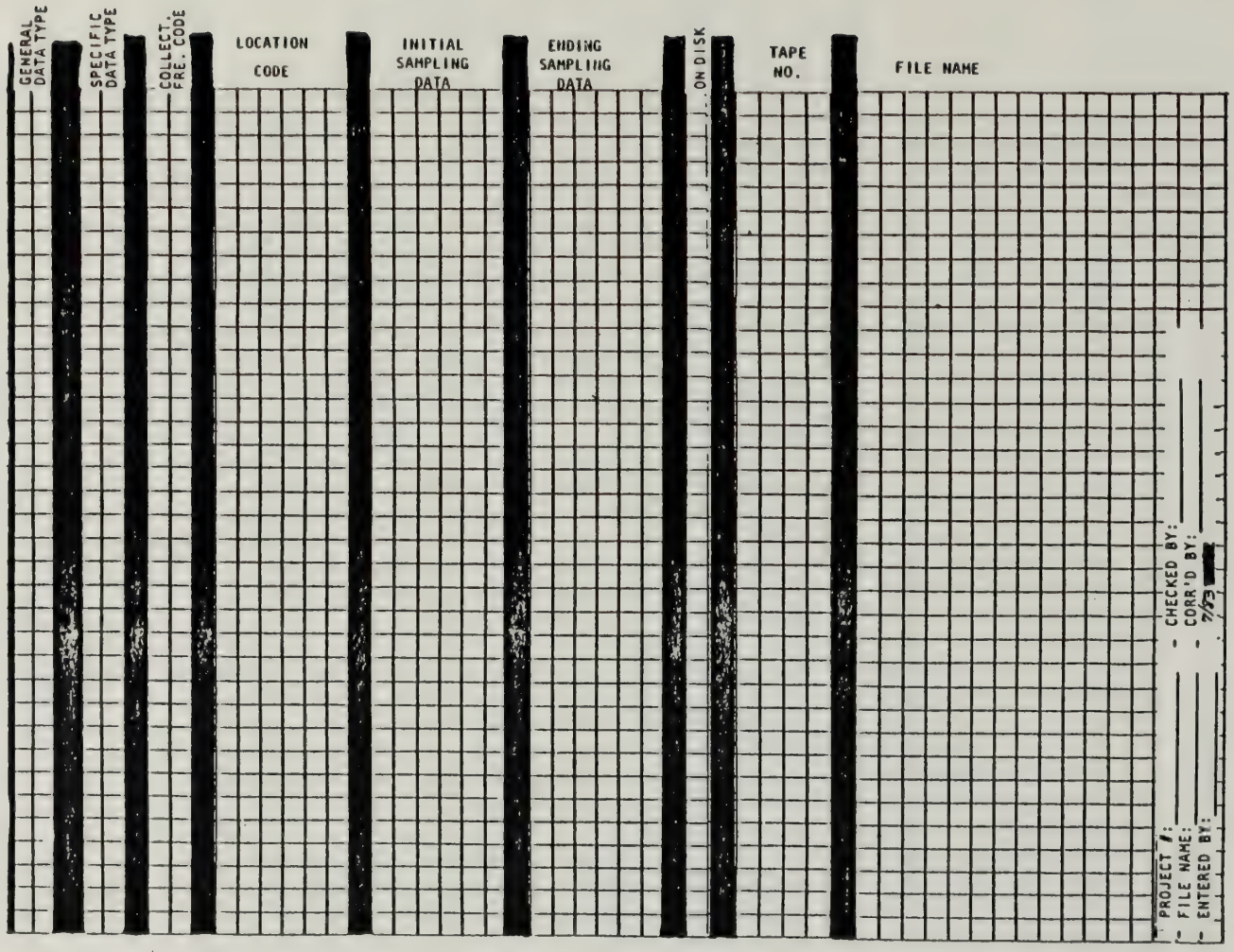

Figure 8.2-1. Sample library coding sheet.

The documentation of the cataloging system will be written to be a "stand alone" user's guide to the system. It will contain information about the setup of the computerized catalog, instructions for transferring data files between tapes and the computer and instructions on how to run the associated software to access the catalog. This document is scheduled to be completed by July, 1984.

This library software will allow the user to determine the location (data file name or tape number) of specific data and determine the availability of specified data types. If the user is interested in knowing when and where annual species biomass production data was collected, the dates of collection and collection sites can be easily obtained. This will be especially useful for coordination of data types from different diciplines for an analysis.

8.2.2 Program Review

A program review undertaken in 1983 considered the overall environmental monitoring program and each of the five individual disciplines including Air Resources, Vegetation, Aquatic Biology, Terrestrial Fauna and Water Resources. The major objective of the review was to evaluate the environmental monitoring program efforts in view of overall program goals as stated in the EMM. The review was not exhaustive but qualitatively addressed the major goal of the monitoring program:

"The major goal of the program is to provide a body of information which describes the ecology of the project area in a manner which will:

1. Allow assessment of changes occurring in the physical and biological characteristics of the tracts as a result of the impact of surface disturbances and pollutant discharges.

2. Guide analysis of cause and effect, thus leading to appropriate mitigation planning.

3. Guide and assess the effectiveness of mitigation and reclamation measures."

The program review recognized that WRSOC, in 8-9 years of data collection, has accumulated an extremely large data base which adequately describes the dominant physical and biological features of the tract ecosystem as a baseline for future comparisons. The program review recommended that the environmental monitoring program needs to change focus from the continuation of descriptive data collection to the selection of more refined monitoring parameters. These are parameters which are sensitive to pollutants and disturbances resulting from oil shale development and which can be measured with enough accuracy for detection of impacts outside of natural variability. This should allow a narrowing of program focus to critical areas with more tightly defined objectives which can, through proper sampling design, enhance the probability of detecting change. The steps involved in this process should be:

1. Identify specific pollutant groups and disturbances. Determine their source, pathways through the environment, their expected areas of impact, and potential symptoms.

2. Based upon these expected pathways and symptoms, identify parameters and relationships that might show the effects of pollutants and/or meet other program objectives.

3. Reevaluate and redefine both overall and single discipline objectives.

4. Refocus and streamline the monitoring program eliminating redundancy and using the best set of parameters and relationships that will detect impacts.

5. Design experiments (special studies), where needed, to look at the effect of pollutants on parameters or relationships.

8.2.3 Evaluation of Precipitation and Evaporation Data

The effort of Ecosystem Analysis to develop or refine ecosystem relationships began logically with a look at driving abiotic parameters and their direct relationships to primary biotic parameters. The first set of analyses considered the relationship of vegetation parameters to climatic factors. Vegetation parameters were selected as they are the biological parameters most closely related to climate and vegetation provides the

primary energy source for terrestrial and much aquatic life.

Two climatic factors of dominant importance to vegetative production are precipitation and evaporation. These were evaluated statistically to determine; 1) if there were spatial and temporal patterns which could be quantified for use in plant production models, and 2) if data collection for these parameters is meeting stated program objectives.

Precipitation data has been collected at many stations since the program began in 1974. Many gages have been moved or discontinued. Since program reorganization in 1981 data collection has been consistently maintained at ten active stations. Discontinuities in the collection of this data presented problems of missing data for statistical analyses and thereby decreased the power of this data base to statistically document differences. However, based on partial data sets it was shown that differences in precipitation may be statistically quantified between months, seasons and years as well as between stations if sufficient years data can be included in the analysis. It was not possible to statistically determine which stations were similar or different although use of Clustar analysis did separate two major groups of different stations. It might be feasible to develop a model which predicts precipitation at different locations based upon data at a control or control stations. Other techniques including isohyetal analysis or use of the Thiessen Polygon may be employed. These approaches were not pursued for this report.

An analysis of evaporation data demonstrated that there are differences in evaporation rates between stations and between months. There was some indication that terrain affects evaporation.

8.2.4 Evaluation of Vegetation Parameters for Monitoring

At the base of the biological food chain and consisting of the biotic parameters driven most directly by abiotic factors, vegetation parameters were chosen for analysis. Of the vegetation parameters in use, annual species biomass production (ASBP) and sagebrush leader growth (SLG) were evaluated as monitoring parameters. A literature review of factors regulating vegetative production in arid environments was conducted to determine the dominant factors for use in development of relationships. A statistical approach was used to determine at what level the effects of oil-shale development could be discerned from natural variability inherent to the parameters. Analysis of variance (ANOVA) was used to partition natural variation into temporal and spatial components. Regression analysis was used to evaluate relationships between temporal variation and climatic factors.

The magnitude of unexplained spatial variation inherent to ASBP creates problems in the detection of effects of oil shale development on any but the global level of resolution. An attempt to explain some of the variability in ASBP using October to May precipitation was not successful. Reevaluation of sampling design with consideration of stratification by soil type and increased replication might be used to increase sensitivity of this parameter.

The magnitude of spatial variation inherent to SLG is low relative to that of temporal variation. A major portion of the temporal variability may be explained due to variability in October to March precipitation and net solar radiation. This relationship results in a relatively high degree of

predictability for measures of SLG. Consequently, a small change in SLG beyond that predicted by climatic factors could be suggestive of effects of development activities. Measures of SLG may be useful in determining an early environmental response to oil shale development.

8.3 PROGRAM DESCRIPTION

8.3.1 Introduction

During 1983 an Ecosystem Analysis program was started by WRSOC. This program was created to provide a mechanism for integrating environmental data from the different environmental monitoring disciplines and providing recommendations to WRSOC for refinements to the environmental monitoring program.

8.3.2 Objectives

Program objectives for Ecosystem Analysis included four major long-term goals with six ancillary goals or tasks. These major goals were:

1. Centralize all environmental data from all disciplines under a uniform library and cataloging system.

2. Develop efficient computer software to perform inter- and intra-disciplinary data analysis.

3. Perform evaluation of existing and potential ecosystem relationships.

4. Develop a complete, documented system which may be operated by WRSOC personnel at a future date.

The tasks required to meet these goals were:

1. Coordinate with WRSOC environmental consultants to obtain necessary data files.

2. Catalog, document and maintain all WRSP environmental data files under a single system.

3. Develop software to analyze for ecosystem relationships and provide a management tool for the WRSP environmental program.

4. Analyze for and identify relationships both within and among the major disciplines, which are ecologically meaningful and provide information concerning impact pathways.

5. Identify data points lying outside of expected confidence limits and which may represent perturbations from natural background levels.

6. Provide recommendations to WRSOC concerning changes in sampling methodology which would reduce the variability and increase the sensitivity of important relationships. It is anticipated that, by focusing the monitoring program on "community-level" parameters

associated with the more important relationships, the efficiency of the WRSP program will improve and overall costs will decrease.

Efforts during 1983 addressed all these program tasks with the exception of No. 5 above. In addition, a subjective program review was undertaken to evaluate the status of the program relative to fulfillment of OSO guidelines as reflected in program goals.

8.4 PROGRAM RESULTS AND ANALYSIS

This section discusses, in detail, the analyses used to determine whether certain parameters measured in the environmental monitoring program are meeting the objectives of the program stated in the EMM. Parameter sets discussed are precipitation, evaporation and vegetation. The outputs of these analyses and their implications to overall program goals of impact identification and pathway detection are discussed. Recommendations for program refinement are presented in the last subsection.

8.4.1 Evaluation of Precipitation and Evaporation Data

8.4.1.1 Introduction The WRSOC monitoring program includes measurements of precipitation, pan evaporation, temperature, relative humidity and wind run. Precipitation and evaporation monitoring data, as described in the Environmental Monitoring Manual, are intended to be used as follows:

1. To assist flood frequency analysis.

2. To verify daily discharge calculations and water quality measurements in perennial and ephemeral water courses.

3. To determine the relationship between the project site and regional precipitation and evaporation data which will be useful to verify the 100-year design storm and analysis of other tract microclimate values.

4. To assist in project design through measurement of site-specific evaporation. This information coupled with output from the first three objectives will provide data to assist in design of holding ponds.

5. To determine the probable water loss from on-tract sites through calculation of water balances. This output is intended for support of revegetation programs and design of processed shale disposal pile.

6. To provide a data base that will support the aquatic, terrestrial biota and revegetation studies being conducted on the tracts.

The overall goal of this data collection scheme is to identify temporal and spatial patterns in precipitation and evaporation which describe the tract environment and allow the attainment of the above stated objectives. Figures 8.4-1 to 8.4-5 are illustrative of variability in temporal patterns in climatic factors

8.4.1.2 Precipitation The object of the analyses in this section is to statistically test whether or not the precipitation data, as collected,

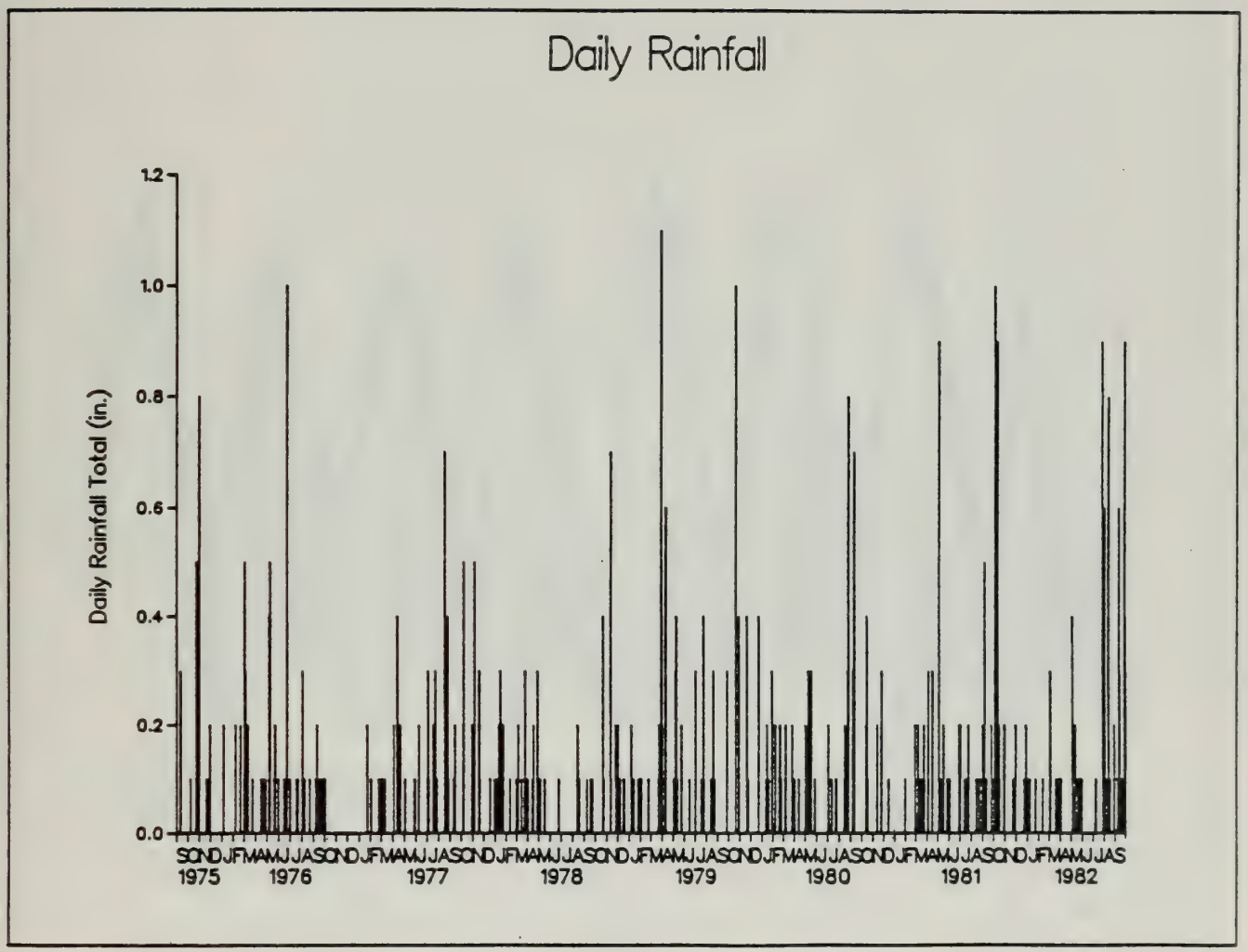

Figure 8.4-1. Totals for each precipitation event at precipitation gage ARA-13.

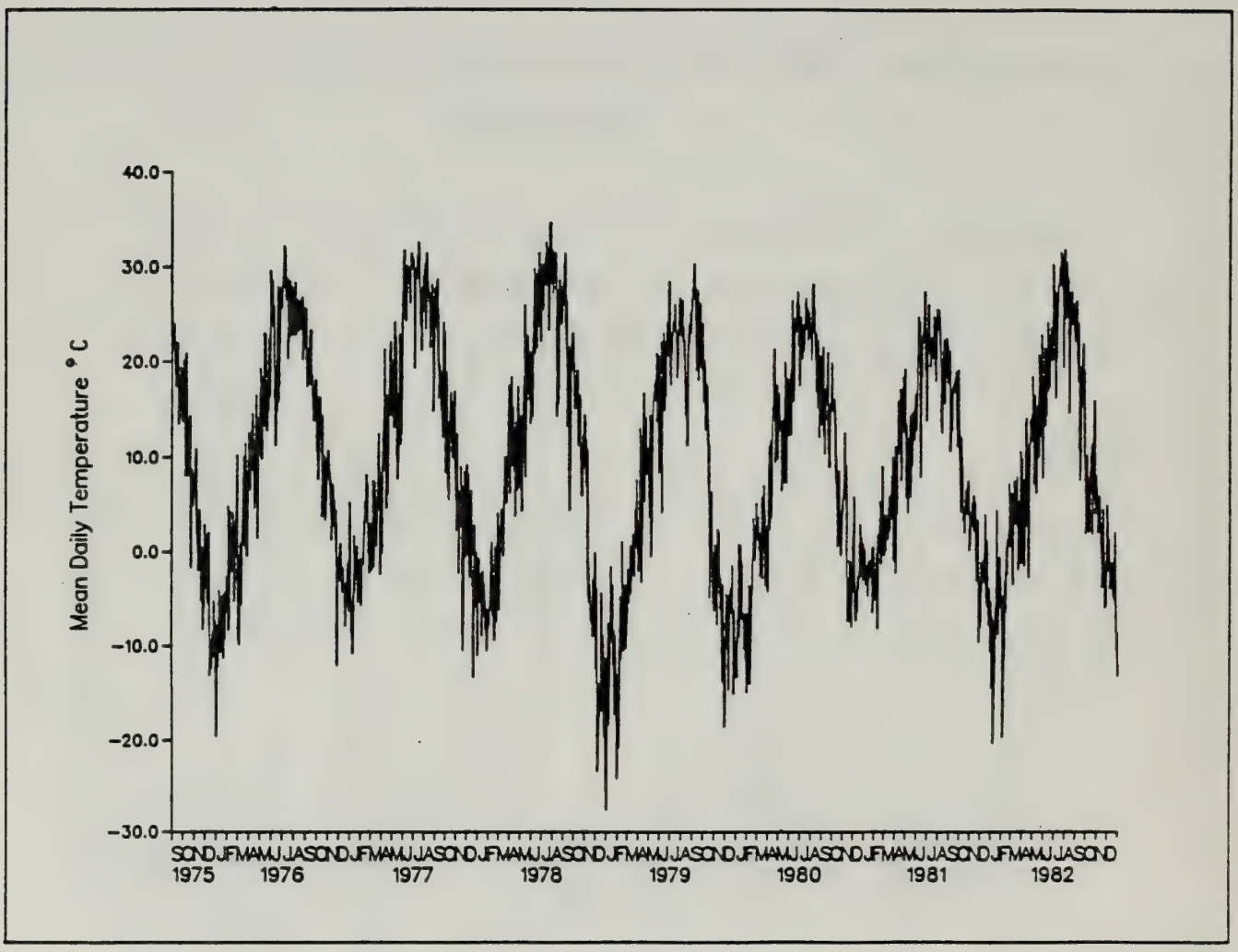

Figure 8.4-2. Mean daily temperature at weather station A-13.

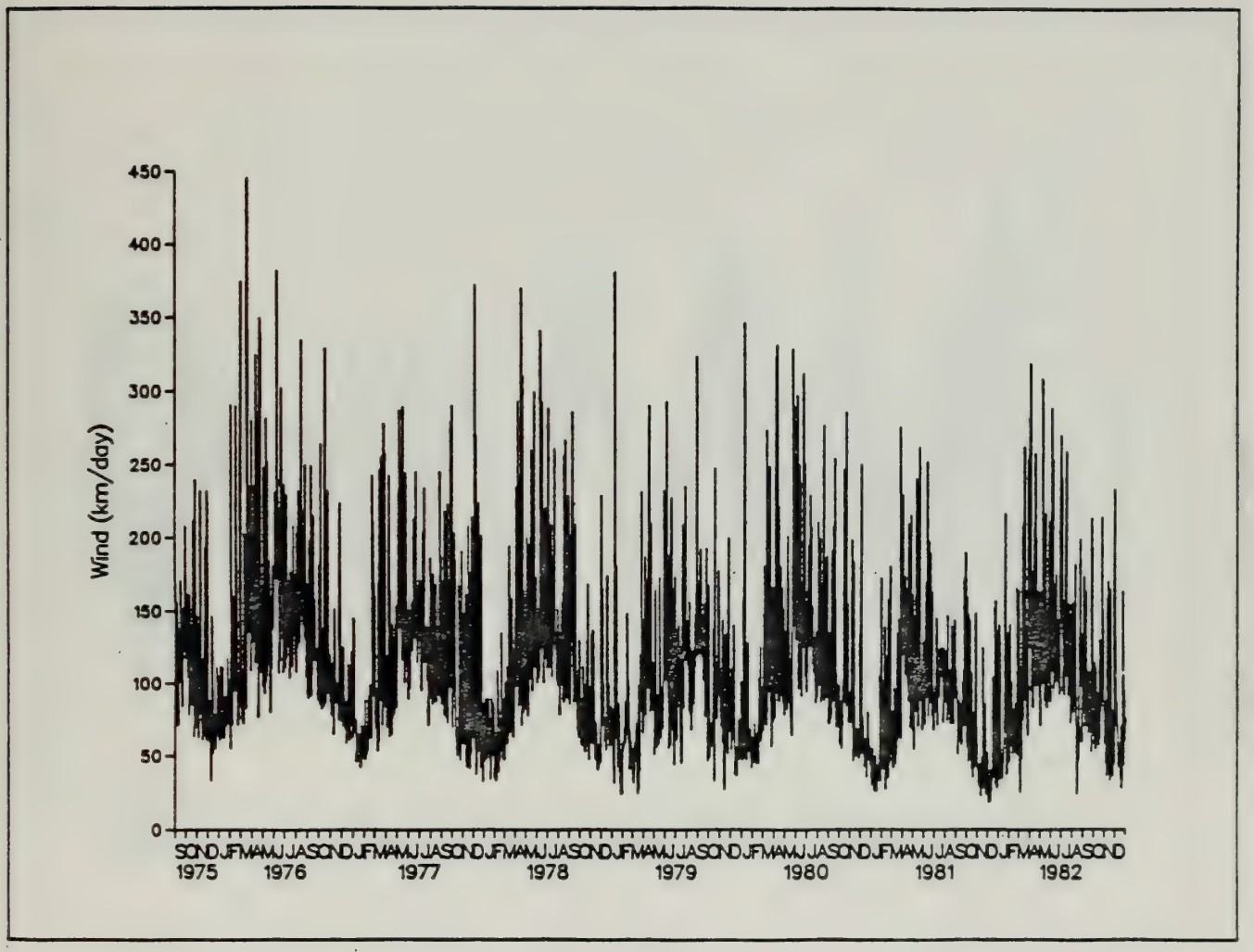

Figure 8. 4-3. Cumulative daily wind speed at weather station A-13.

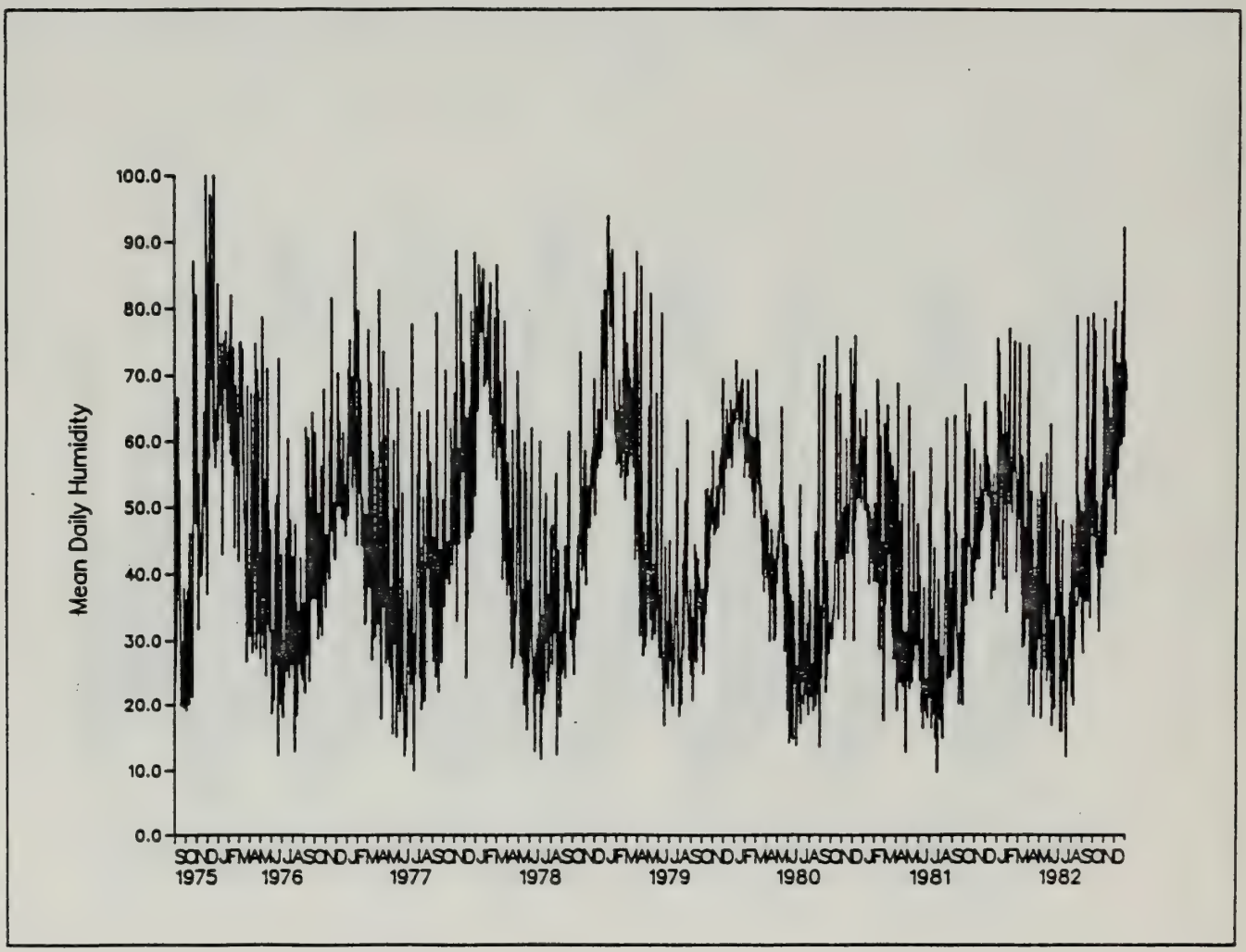

Figure 8.4-4. Mean daily relative humidity at air quality station A-6.

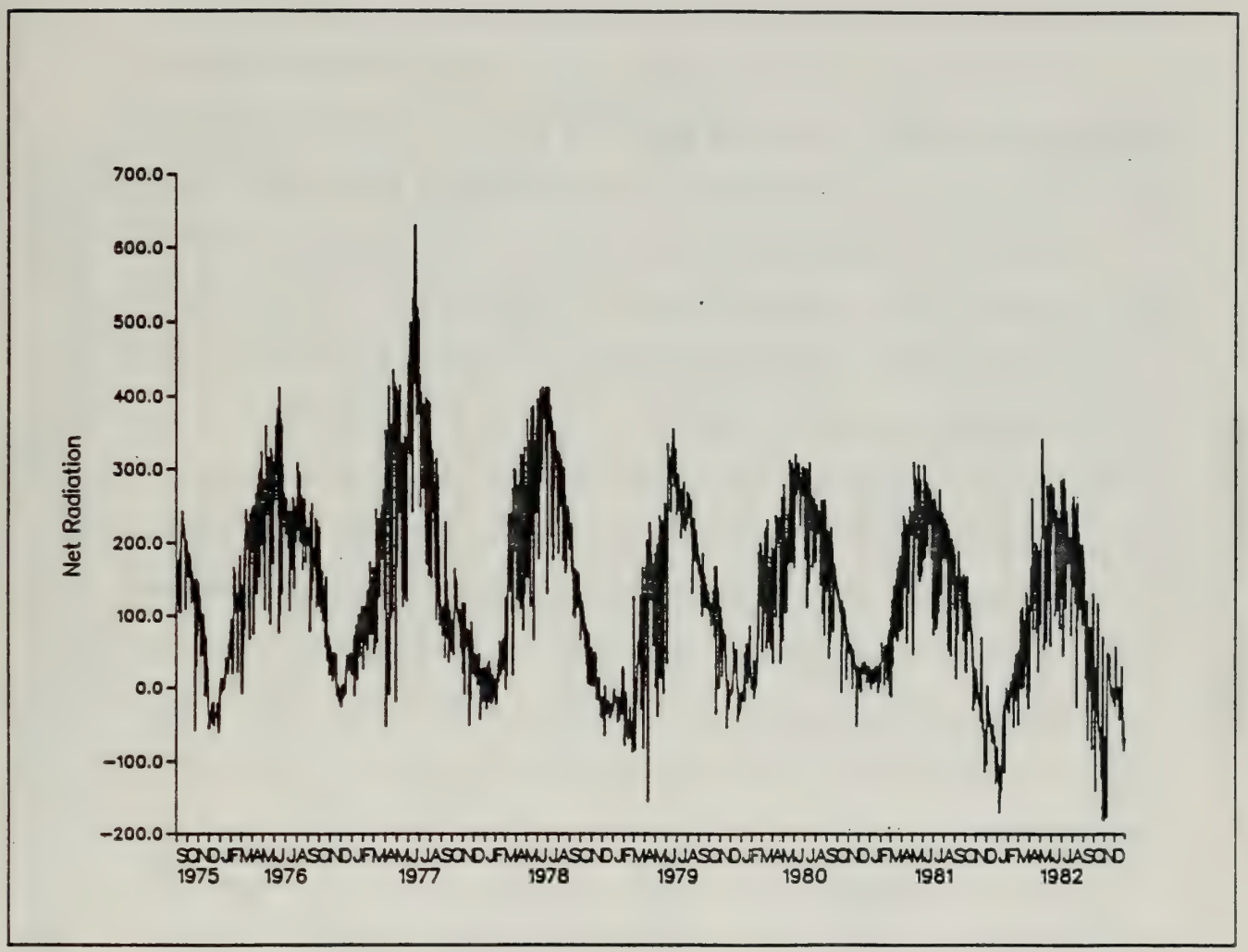

Figure 8.4-5. Net solar radiation (langleys/day) at air quality station A-6.

allows identification of temporal and spatial differences and at what level of resolution these differences are discernable. For each analysis the most complete data set available was used to make meaningful comparisons.

A presence-absence matrix (Table 8.4-1) was generated from the precipitation data. This table shows the pattern of precipitation data collection since the inception of the environmental program for the WRSP.

Since 1974, twenty-nine different locations have been monitored for precipitation data, although not all simultaneously. During the baseline period of 1974-1976, precipitation data was collected at monthly intervals for as many as 20 stations and daily totals were recorded for six automatically recording stations. During the lease suspension period of 1977-1981, the number of stations monitored was markedly reduced with three to eleven stations being active. Three automatic recording gages were maintained during this period. Following the lease suspension period (1981 to present) the program was streamlined to include seven manual gages providing monthly total precipitation and three automatic gages providing daily totals.

During this eight-year period of data collection, it has been observed that spatial and temporal patterns of precipitation exist. For some applications, such as vegetation analysis or flood frequency/discharge analysis, it is important to know the precipitation at vegetation monitoring sites or for drainage basins of interest. Thus it could be important to develop relationships based upon these spatial or temporal differences which allow prediction of precipitation at non-monitored locations.

Table 8.4-1. Matrix of precipitation data collection since 1974.
M = monthly total precipitation at manual gages.
D = daily total precipitation at automatic recording gages.

	STATIONS																												
DATE	RA 2	RA 4	RA 8	RB 1	RP 1	RS 1	RS 2	RS 3	RS 4	RS 6	RS 7	RS 8	RS 9	RV 7	RV 8	ARA 2	ARA 4	ARA 8	ARP 1	ARS 4	ARS 9	RA 13	RS 10	RS 11	RS 12	RS 13	RS 15	ARA 13	ARS 12
10/1974					M	M	M	M	M	M	M	M	M			D	D	D		D			M	M	M	M	M		D
11/1974					M	M	M	M	M	M	M	M	M			D	D	D		D			M	M	M	M	M		D
12/1974					M	M	M	M	M	M	M	M	M			D	D	D		D			M	M	M	M	M		D
1/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
2/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
3/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
4/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
5/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
6/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
7/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M			D
8/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
9/1975					M	M	M	M	M	M	M	M	M			D	D	D	D	D			M	M	M	M	M		D
10/1975						M		M		M			M			D		D	D	D	D	M			M	M			D
11/1975						M		M		M			M			D		D	D	D	D	M			M	M			D
12/1975						M		M	M	M			M			D		D	D	D	D	M			M	M			D
1/1976			M			M		M	M	M			M			D		D	D	D	D	M			M	M			D
2/1976	M		M		M	M			M	M			M			D		D	D	D	D				M	M			D
3/1976	M		M		M	M			M	M			M			D		D	D	D	D	M			M	M			D
4/1976	M		M		M	M			M	M			M			D		D	D	D	D	M			M	M			D
5/1976	M		M		M	M			M	M			M			D		D	D	D	D	M			M	M			D
6/1976	M		M		M	M			M	M			M			D		D	D	D	D	M			M	M			D
7/1976	M		M		M	M			M	M			M			D		D	D	D	D	M			M	M			D
8/1976	M		M		M	M			M	M			M			D		D	D	D	D	M			M	M			D
9/1976	M		M		M	M			M	M			M			D		D	D		D	M			M	M		D	D
10/1976					M	M				M			M			D					D				M	M		D	
11/1976					M	M				M			M			D					D				M	M		D	
12/1976					M								M			D					D					M		D	
1/1977																D					D							D	
2/1977																D					D							D	
3/1977							M						M			D					D	M				M		D	
4/1977							M						M			D					D	M				M		D	
5/1977							M					M	M			D					D	M				M		D	
6/1977							M					M	M			D					D	M				M		D	
7/1977							M					M	M			D					D	M				M		D	
8/1977							M					M	M			D					D	M				M		D	
9/1977							M					M	M			D					D	M				M		D	
10/1977	M												M	M	M	D						M				M		D	
11/1977														M	M							M						D	
12/1977														M	M							M						D	
1/1978														M								M						D	
2/1978														M	M							M						D	
3/1978														M	M							M						D	
4/1978	M	M											M	M	M	D					D	M				M		D	
5/1978	M	M											M	M	M	D					D	M				M		D	
6/1978	M	M														D					D	M				M		D	
7/1978	M	M											M	M	M	D					D	M						D	
8/1978	M	M											M	M	M	D					D	M				M		D	
9/1978	M	M											M	M	M	D					D	M				M		D	
10/1978	M	M											M	M	M	D					D	M		M		M		D	
11/1978	M	M											M	M	M							M		M		M		D	
12/1978	M	M											M	M	M							M		M		M		D	

Table 8.4-1. (Continued).

	STATIONS																												
DATE	RA 2	RA 4	RA 8	RB 1	RP 1	RS 1	RS 2	RS 3	RS 4	RS 6	RS 7	RS 8	RS 9	RV 7	RV 8	ARA 2	ARA 4	ARA 8	ARP 1	ARS 4	ARS 9	RA 13	RS 10	RS 11	RS 12	RS 13	RS 15	ARA 13	ARS 12
1/1979	M	M											M	M	M							M		M		M		D	
2/1979	M	M											M	M	M							M		M		M		D	
3/1979	M	M											M	M	M	D					D	M		M		M		D	
4/1979	M	M											M	M	M	D					D	M		M		M		D	
5/1979	M	M											M	M	M	D					D	M		M		M		D	
6/1979	M	M											M	M	M	D					D	M		M		M		D	
7/1979	M	M											M	M	M	D					D	M		M		M		D	
8/1979	M	M											M	M	M	D					D	M		M		M			
9/1979	M	M											M	M	M	D					D	M		M		M		D	
10/1979		M					M						M	M	M	D					D	M		M		M		D	
11/1979		M					M						M	M	M							M		M		M		D	
12/1979		M					M						M	M	M							M		M		M		D	
1/1980		M					M						M	M	M							M		M		M		D	
2/1980		M					M						M		M							M		M		M		D	
3/1980		M					M						M	M	M							M		M		M		D	
4/1980		M					M						M	M	M	D					D	M		M		M		D	
5/1980		M					M						M	M	M	D					D	M		M		M		D	
6/1980		M					M						M	M	M	D					D	M		M		M		D	
7/1980		M					M						M	M	M	D					D	M		M		M		D	
8/1980		M					M						M	M	M	D						M		M		M		D	
9/1980		M					M						M	M	M	D					D	M		M		M		D	
10/1980	M	M											M	M	M	D					D	M		M		M		D	
11/1980	M	M											M	M	M									M		M		D	
12/1980	M	M											M	M	M									M		M		D	
1/1981	M	M											M	M	M									M		M		D	
2/1981	M	M											M	M	M									M		M		D	
3/1981	M	M		M									M	M	M								M	M		M		D	
4/1981		M		M										M	M	D					D		M	M		M		D	
5/1981		M		M										M	M	D							M	M		M		D	
6/1981		M		M										M	M	D							M	M		M		D	
7/1981		M		M										M	M	D					D		M	M		M		D	
8/1981		M		M										M	M	D					D		M	M		M		D	
9/1981		M		M										M	M	D					D		M	M		M		D	
10/1981		M		M										M	M	D					D		M	M		M		D	
11/1981		M		M										M	M								M	M		M		D	
12/1981		M		M										M	M								M	M		M		D	
1/1982		M		M										M	M								M	M		M		D	
2/1982		M		M										M	M								M	M		M		D	
3/1982		M		M										M	M								M	M		M		D	
4/1982		M		M										M	M	D					D		M	M		M		D	
5/1982		M		M										M	M	D					D		M	M		M		D	
6/1982		M		M										M	M	D					D		M	M		M		D	
7/1982		M		M										M	M	D					D		M	M		M		D	
8/1982		M		M										M	M	D					D		M	M		M		D	
9/1982		M		M										M	M	D					D		M	M		M		D	
10/1982		M		M										M	M	D					D		M	M		M		D	
11/1982		M		M										M	M	D					D		M	M		M		D	

The precipitation data was analyzed to determine if the data collection scheme was effective in characterizing differences in precipitation between time periods (years, seasons, months) and between gage locations.

The first analysis undertaken used a two-way ANOVA to test the following hypotheses:

H_{01}: The total precipitation in each month is equal.

H_{02}: The total precipitation within each gage location was equal to all others.

In all cases, the analysis indicated that there were significant differences in precipitation between months ($p<0.001$) and that H_{01} should be rejected. The results of the two-way ANOVA testing whether the precipitation was different between gage locations (H_{02}) are presented in Table 8.4-2. For any single water year there was no significant difference in mean monthly precipitation between stations. Thus, H_{02} was accepted for single water year data.

Both hypotheses H_{01} and H_{02} were then tested over several water years using two-way ANOVA. These analyses were based upon the appropriate subsets of data from the previous analysis. Again, differences between monthly precipitation were highly significant ($p<.001$). However, significant differences were found between station means for the periods 1974-1976 ($p<0.01$) and 1979-1982 ($p<0.05$) (see Table 8.4-2). Both hypotheses were rejected for periods of more than one water year.

Table 8.4-2. Results of two-way ANOVA testing for differences between precipitation gage locations within single years and over several years based upon total monthly precipitation and total water year precipitation.

Water Year	Number of Stations Included[1]	F-Statistic	Probability Level
1974-1975	8	1.77	0.106 N.S.
1975-1976	8	2.01	0.066 N.S.
1978-1979	8	0.69	0.684 N.S.
1979-1980	7	1.21	0.312 N.S.
1980-1981	5	1.70	0.141 N.S.
1981-1982	7	1.00	0.433 N.S.
1974-1976[2]	8	2.97	0.006 S.
1979-1982[2]	5	3.17	0.016 S.
1978-1982[3]	6	3.28	0.034 S.

[1] See Table 8.4-1 for gages included in each analysis. Gages used were those with complete records during the period 1974-1976 (RS-1, RS-6, RS-9, ARA-9, RS-1, RS-6, RS-9, ARA-9).

[2] These multiple year periods were tested using total monthly precipitation values.

[3] This multiple year period was tested using total water year precipitation.

Repeating the same analysis and testing for differences between stations using total water year precipitation gave similar results (Table 8.4-2).

The next analysis considered the seasonal aspect of precipitation data. Summer data only was considered, as a large number of stations were available for analysis. In this analysis a two-way ANOVA was used to test the following hypotheses:

H_{01}: The total precipitation in each month for the summer period April-September was equal.

H_{02}: The precipitation for the period April-September was the same for all stations.

Again, H_{01} was rejected and monthly totals were shown to be significantly different ($p<0.05$). The results of the analysis testing H_{02} are shown in Table 8.4-3. The hypothesis was not rejected as no significant differences were observed between stations either for single year monthly totals or multiple year monthly totals.

Based upon the previous analyses, it was evident that precipitation was different between months, seasons and years. Also, if sufficient years data were included differences may be shown between stations. This suggests that differences between stations are small and are detectable only when a considerable period of time is considered. A clustar analysis was used to attempt to identify patterns for seasonal precipitation for the water years 1977-1980. This analysis was performed using gages RS-9, ARS-9, RA-4, RA-13,

Table 8.4-3. Results of two-way ANOVA testing for differences between precipitation gage locations based on total monthly precipitation for the period April through September.

Water Year	Number of Stations Included[1]	F-Statistic	Probability Level
1979	6	1.34	0.279 N.S.
1980	6	1.29	0.300 N.S.
1981	6	1.11	0.382 N.S.
1982	6	1.92	0.128 N.S.
1979-1982	6	1.62	0.161 N.S.

[1] Stations RA-4, RV-7, RV-8, ARA-2, RS-11 and RS-13 were included in the analysis.

ARA-13, ARA-2, RS-13, RV-7, RV-8, RS-11.

The results of the clustar analysis are shown in Figure 8.4-6. Two clusters are apparent. One containing RS-9, ARS-9 and RA-4. The other containing RA-13, ARA-13, ARA-2, RS-13, RV-7, RV-8 and RS-11. The smaller cluster containing RS-9, ARS-9 and RA-4 was at the extreme southeast corner of the tracts. Precipitation has generally been assumed to be highest at the southeast and lowest at the northwest. The clustar analysis supports an expected difference between these locations. However, a comparison of data for selected stations from the cluster did not reveal any trends except that station RS-13, near the White River at the northwest corner of the tracts, had a higher total precipitation during 1980-1982 (Table 8.4-4). All other locations appeared to be very similar.

It was concluded from these analyses that temporal and spatial differences in precipitation do occur on Tracts Ua and Ub. It is known,

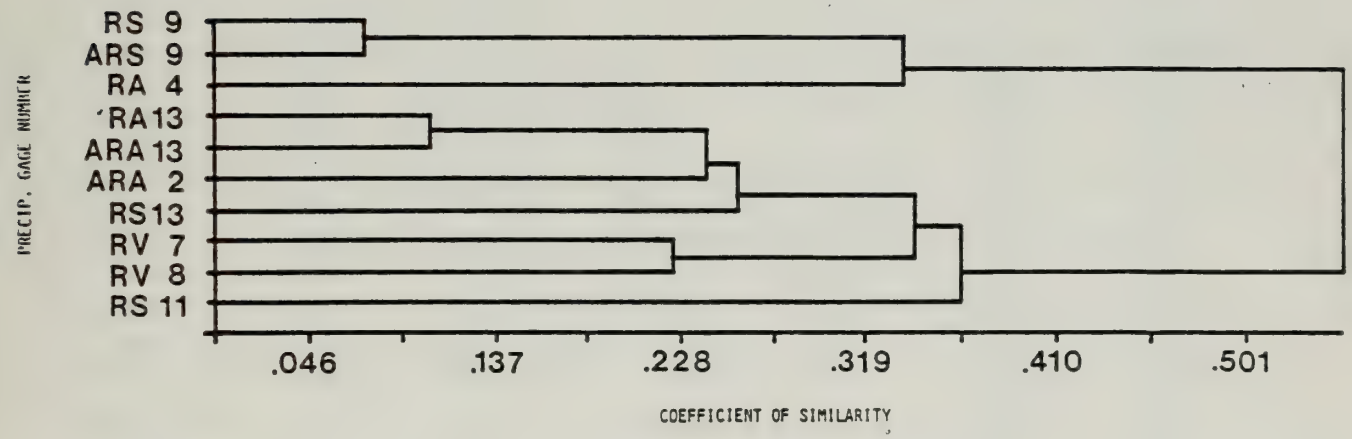

Figure 8.4-6. Results of clustar analysis for nine precipitation gage locations.

Table 8.4-4. Monthly precipitation values in inches during 1981 and 1982 water years for stations included in clustar analysis. Stations RS-9, RA-13, RV-7, and RV-8 were not included due to sparse data during this period.

PRECIPITATION GAGE NUMBER AND LOCATION
RELATIVE TO TRACTS UA AND UB

	SOUTHEAST		CENTER		NORTHWEST	
Date	RA-4	ARS-9	ARA-2	ARA-13	RS-11	RS-13
10/80	0.96	1.00	0.70	0.90	0.99	0.97
11/80	0.43			0.50	0.39	0.52
12/80	0.28			0.10	0.10	0.21
1/81	0.12			0.10	0.18	0.16
2/81	0.33			0.30	0.26	0.34
3/81	1.11			0.80	0.61	1.05
4/81	0.80	0.70	0.50	0.60	0.40	0.21
5/81	1.83		1.70	1.60	1.60	1.84
6/81	0.53		0.20	0.30	0.40	0.30
7/81	1.05	0.90	0.80	0.80	1.22	1.09
8/81	1.03	1.00	0.50	0.60	0.61	0.83
9/81	0.80	0.70	0.80	0.80	0.95	0.76
10/81	3.70	3.40	3.60	3.40	3.40	3.39
11/81	0.56			0.50	0.62	0.50
12/81	0.65			0.30	0.27	0.31
1/82	0.31			0.30	0.43	0.24
2/82	0.00			0.10	0.00	0.00
3/82	1.56			1.10	1.45	1.39
4/82	0.00	0.10	0.30	0.10	0.00	0.00
5/82	0.86	1.00	1.40	1.10	1.14	1.60
6/82	0.10	0.00	0.20	0.00	0.11	0.17
7/82	1.23	0.90	1.00	1.40	1.23	1.68
8/82	1.90	1.90	2.80	2.00	1.83	2.82
9/82	3.23	3.40	3.00	3.10	3.44	3.63
	23.37			20.80	21.63	24.01
	(15.66)*	(15.00)	(15.60)	(14.80)	(15.32)	(17.15)

* Numbers in parentheses are totals for months when data were collected at ARS-9. These are for comparison across stations.

however, that precipitation events in deserts are extremely patchy in nature (Noy-Meir 1973). This tendency towards patchiness and discontinuities in data collection has made it difficult to statistically document these patterns and develop a statistical predictive model which will allow for the prediction of precipitation at locations not monitored.

8.4.1.3 Evaporation The object of the analyses in this section was to determine if evaporation data collection allows the statistical detection of hypothesized temporal and spatial differences.

A presence/absence matrix generated from the evaporation data illustrates the pattern of evaporation data collection since the beginning of the environmental program (Table 8.4-5). Since 1975, data has been collected at a total of three sites, with only two in operation simultaneously. Since 1977, EVP-13 at Plant Site Wash and EVP-2 at the prospective shale disposal site in upper Southam Canyon have operated continuously in the frost-free period, May-September. The evaporation pan in Southam Canyon is on an exposed ridge while the pan in Plant Site Wash is in a canyon. These two locations were selected to allow a demonstration of differences due to terrain and wind effects.

Two analyses were undertaken to determine if spatial and temporal differences occurred between EVP-2 and EVP-13. EVP-6 was not considered due to its shorter term data base. The first analysis tested the following hypotheses through two-way ANOVA:

H_{01}: Evaporation was not different between sites.

Table 8.4-5. Matrix of evaporation data collection since 1975.
M = monthly total evaporation recorded.

DATE	EVP-2	EVP-6	EVP-13
5/1975	M	M	
6/1975	M	M	
7/1975	M	M	
8/1975	M	M	
9/1975	M	M	
10/1975	M	M	
11/1975	M	M	
12/1975			
1/1976			
2/1976			
3/1976			
4/1976			
5/1976	M	M	
6/1976	M	M	
7/1976	M	M	
8/1976	M	M	
9/1976	M	M	
10/1976			
11/1976			
12/1976			
1/1977			
2/1977			
3/1977			
4/1977			
5/1977	M		
6/1977	M		M
7/1977	M		M
8/1977	M		M
9/1977	M		M
10/1977			
11/1977			
12/1977			
1/1978			
2/1978			
3/1978			
4/1978			
5/1978	M		M
6/1978	M		M
7/1978	M		M
8/1978	M		M
9/1978	M		M
10/1978			
11/1978			
12/1978			
1/1979			
2/1979			
3/1979			
4/1979			
5/1979	M		M
6/1979	M		M
7/1979	M		M
8/1979	M		M
9/1979	M		M
10/1979			
11/1979			
12/1979			

DATE	EVP-2	EVP-6	EVP-13
1/1980			
2/1980			
3/1980			
4/1980			
5/1980	M		M
6/1980	M		M
7/1980	M		M
8/1980	M		M
9/1980	M		M
10/1980			
11/1980			
12/1980			
1/1981			
2/1981			
3/1981			
4/1981			
5/1981	M		M
6/1981	M		M
7/1981	M		M
8/1981	M		M
9/1981	M		M
10/1981			
11/1981			
12/1981			
1/1982			
2/1982			
3/1982			
4/1982			
5/1982	M		M
6/1982	M		M
7/1982	M		M
8/1982	M		M
9/1982	M		M

H_{02}: Total monthly evaporation during any one month was not different from any other month.

The results of this analysis are presented in Table 8.4-6. Both hypotheses were rejected as differences were highly significant between sites and months.

Table 8.4-6. ANOVA for evaporation data from EVP-2 and EVP-13 testing differences between sites and months using monthly total evaporation.

Source	DF	SS	MS	F	P
Month	28	154.85	5.53	3.35	0.001 S.
Site	1	24.36	24.36	14.76	0.0006 S.
Error	28	46.07	1.65		
Total	57	225.28			

An additional two-way ANOVA was performed using the annual mean of monthly values for each summer (May - September) to test the following hypotheses:

H_{01}: Evaporation for the summer months was not different between sites.

H_{02}: Mean monthly evaporation for any one summer was not different from any other summer.

Table 8.4-7 is a presentation of the results of this analysis. H_{01} was accepted and it was concluded that summer evaporation doesn't vary from year to year. However, H_{02} was rejected and it was concluded that average monthly evaporation did vary between sites.

Table 8.4-7. ANOVA for evaporation data from EVP-2 and EVP-13 testing for differences between sites and years using the mean of monthly values for the months May to September.

Source	DF	SS	MS	F	P
Year	4	5.463	1.366	1.954	0.2662 N.S.
Site	1	5.790	5.790	8.283	0.0452 S.
Error	4	2.795	0.699		
Total	9	14.048			

Based upon these analyses, evaporation data collection has demonstrated that spatial differences in evaporation do occur on Tracts Ua and Ub. Based on either monthly or annual data, temporal differences are only apparent at the month level.

8.4.1.4 Discussion The analyses performed on precipitation and evaporation data have demonstrated that the expected spatial and temporal differences on the Tracts do occur.

For precipitation data within years, no differences were shown between stations while differences did become distinguishable over longer time periods. This could mean that there are no short-term differences between stations or there are differences which the program lacks the resolution to detect. The latter case is suspected as analyses including monthly totals

over several years (thus increasing the power of the statistics) do show differences. Analyses using daily values might also demonstrate these differences. Daily value analyses were not attempted.

The hypothesis of elevational differences in precipitation was not documented and would probably require many more years of data in a balanced design or greater elevational change to document. In a regional sense with large increments in elevation these patterns would show clearly. No trend of increasing precipitation from northwest to southeast was documented but clustar analysis did indicate two distinctly different groups of stations. One group was in the northern area of the tracts and the other in the southern. Inspection of actual precipitation amounts for the 1981 and 1982 water years for those locations show RS-13 at the White River to be higher than all the other stations among those considered with the remainder of the stations equal. In 1981 RA-4 had higher precipitation than other stations. Based upon these observations, it appears the precipitation pattern across tracts is variable from year to year.

The conclusion to be drawn from these analyses is that if precise precipitation data is needed for a particular location, a gage should be located at that point. This has been done for the prospective shale disposal site and the Plant Site Wash.

Evaporation data did show spatial and temporal differences which were expected to occur due to terrain effects. With only two stations in the sampling design no definite trend with elevation, slope, aspect or vegetation cover could be documented. However, the location of the evaporation pans in a site-specific manner to address questions of evaporation for the proposed

shale disposal site and Plant Site Wash Reservoir was appropriate. With no ability to extrapolate the evaporation data to other sites, the same conclusion was drawn as for precipitation. Evaporation pans should be placed wherever there is a specific need for the data.

8.4.2 Evaluation Of Vegetation Parameters For Monitoring

8.4.2.1 Introduction A fundamental purpose of monitoring environmental parameters on Tracts Ua and Ub is to enable potential effects of oil-shale development to be distinguished from variation inherent to natural systems. Development activities may effect a response through:

1. Physical disturbance of surface.

2. Gaseous emissions of pollutants and dust from construction activities.

3. Transport of soluble pollutants through runoff, runon or subsurface drainage.

Critical qualities of monitoring parameters are that they be sensitive to expected impacts of development and that effects of development be discernable from natural variation inherent to the parameter. Timely cognizance of the effects of development may be useful for planning and application of mitigation measures to limit or preclude irreversible degradation.

An effective monitoring parameter must be predictable over the range in spatial variability inherent to the area of concern and the range in temporal variability inherent to natural systems. A high degree of error in predicting spatial and temporal variation inherent to a monitoring parameter results in a low degree of discernability for distinguishing effects of

development from those occurring due to natural variation.

The main objectives of this analysis are to develop relationships between climatic factors and vegetation parameters and to evaluate and suggest refinements for portions of the vegetation monitoring program. Specific objectives are:

1. To evaluate annual species biomass production (ASBP) and sagebrush leader growth (SLG) as monitoring parameters.

2. To suggest refinements which may increase the usefulness of ASBP and SLG as monitoring parameters.

3. Develop relationships between climatic factors and vegetation parameters which will be helpful in determining the cause of any observed changes in vegetation production.

A concise statistical approach is used to evaluate annual species biomass production (ASBP) and sagebrush leader growth (SLG) as monitoring parameters. Statistical procedures are developed for determining the minimal change which could be attributed to development activities. Analysis of Variance (ANOVA) and multiple comparison techniques are used to test hypotheses of differences between mean determinations. Regression analysis is used to evaluate relationships between dependent parameters and climatic variables. The discernability of effects of development upon ASBP and SLG is evaluated relative to variation not explained by significant relationships.

8.4.2.2. A Review of Factors Affecting Plant Productivity In Cold Desert Ecosystems The variation in plant productivity in arid ecosystems is a response to complex interrelations between temporal and spatial factors. Temporal variation in productivity of relatively undisturbed ecosystems is most often attributed to climatic variables. Spatial variation in plant productivity may be a response to interrelations between geomorphic, hydrologic, pedogenic and floristic factors. Spatial variability in arid ecosystems is commonly attributed to factors which influence the proportion of precipitation available to growing plants and the distribution of available nutrients. The effects of microclimate may also contribute to a spatial variation in plant productivity.

Transpiration is closely related to productivity through the simultaneous loss of water and uptake of carbon dioxide through open stomates in the process of photosynthesis (Major 1963, Webb et al. 1978, Szarek 1979). Also transpiration is a response to the simultaneous availability of water and energy which are the two most limiting requirements of photosynthesis (Rosenzweig 1968). Numerous studies have found strong correlations between estimates of evapotranspiration and plant production in arid and semiarid regions (Major, 1963; Webb et al., 1978; Szarek, 1979). Evapotranspiration combines information on precipitation, net radiation, relative humidity and wind speed into a comprehensive evaluation of the environmental conditions that affect photosynthesis and productivity.

A review of literature and conceptual development are presented with respect to primary factors thought to influence temporal and spatial variation in plant productivity for arid environments.

A. Climatic Variables Climatic variables affect the flux of water across the soil/atmosphere interface. Precipitation constitutes the principal source of water entering the terrestrial system while temperature, relative humidity, radiation and wind velocity exert a driving force to water cycling through terrestrial systems. Measures of annual, seasonal and diurnal variation in plant production are most frequently associated with annual, seasonal and diurnal variation in climatic variables.

1. Precipitation In desert ecosystems, aridity is commonly limiting to plant activity. Photosynthesis involves the simultaneous loss of water and uptake of carbon dioxide through open stomates (Noy-Meir, 1973; Fischer and Turner, 1978; Cunningham et. al.; 1979; Louw and Seely, 1982). Although a few studies indicate that productivity is correlated with total annual precipitation (Harris and Campbell, 1981; Passey et al., 1982), other investigations indicate that the seasonal distribution of precipitation events are equally or more significant (Passey and Hugie, 1963; Romney et al., 1974; Hodgkinson et al. 1978; Szarek, 1979; Reynolds and Cunningham, 1981).

In the Intermountain West, summer precipitation is often the product of isolated convective storms. Summer precipitation is often ineffective due to high evaporation rates. The distribution of summer precipitation is often patchy and may vary considerably over relatively short distances. Both forecasts of summer precipitation and extrapolation of rainfall amounts from one location to another are often unreliable.

Most of the effective annual precipitation in the Intermountain West occurs as snow during fall and winter months. Fall and winter precipitation

is generally associated with frontal storm systems which result in relatively homogeneous precipitation over extensive areas of similar topographic relief. Evaporation and transpiration are minimal throughout these months and precipitation is generally more effective in recharging soil water storage.

Many researchers suggest significant relationships between various combinations of seasonal precipitation and plant production. Webb et al. (1978) determined that productivity in cold desert communities is correlated with fall (October through December) precipitation of the previous year. Herbage yields in the Intermountain West have been found to be related to winter/spring precipitation (Sneva and Hyder, 1962). In southeastern Idaho, grass production has been found to be significantly correlated with spring precipitation (Harris et al., 1972; Pearson, 1975). Other studies indicate relationships between sagebrush (Artemisia tridentata) production and fall through spring precipitation (West and Gun, 1974; Daubenmire, 1975; Pearson, 1975), between crested wheatgrass (Agropyron cristatum) and October through May precipitation (Currie and Peterson, 1966), and between winter annuals and winter precipitation (Beatley, 1975, 1976; Harris and Cambell, 1981). These studies indicate that the timing of precipitation with respect to critical phenological stages in floristic development contribute to the effectiveness of precipitation in increasing plant productivity.

The magnitude of a given precipitation event contributes to the effectiveness of that event. Light precipitation may benefit shallow rooted annuals but a heavy precipitation event may be necessary to be significant to large shrubs (Klikoff, 1967). Fogel (1981) and Bell (1979) estimate that at least .20 mm per day is necessary to be effective in arid areas. Other

researchers indicate that the effectiveness of a given precipitation event must be measured relative to the rate of evaporation (Trumble and Woodroffe, 1954; Bailey, 1981; Thames and Evans, 1981). Hillel and Tadmor (1962) suggest that for precipitation to be effective it must penetrate at least 10 cm of soil. These studies indicate that, relative to plant production, the effectiveness of precipitation must be determined in conjunction with other parameters.

2. Temperature Temperature is often considered to be an important factor in determining plant activity (Swartzmann and VanDyne, 1972; Noy-Meir, 1973; DePuit, 1979). Plant species exhibit an optimum temperature at which net photosynthesis is at a maximum (DePuit and Caldwell, 1975). Each species also exhibits a tolerance range of temperatures outside of which net photsynthesis is zero, negative or damage to the plant tissue occurs. Values of optimum, maximum and minimum temperatures are dependent on plant species, ecotype and previous temperature conditions. Some species acclimate to higher temperatures as the growing season progresses (DePuit and Caldwell, 1973). Cool temperatures limit cheatgrass (Bromus tectorum) productivity (Rickard, 1962). Bluebunch wheatgrass (Agropyron spicatum) exhibits an optimum growth at 20 to 25°C (DePuit and Caldwell, 1975). Sagebrush (Artemisia tridentata), shadscale (Atriplex confertifolia), winterfat (Ceratoides lanata), Indian rice grass (Oryzopsis hymenoides), arrowleaf balsamroot (Balsamorhiza sagittata), and native grasses and forbs in the upper Snake River Plain each exhibit a unique response to spring temperatures (Blaisdell, 1958; West and Gunn, 1974; Pearson, 1975).

The direct relationship between increasing temperature and evapotranspiration is also expected to affect responses in plant growth. Summer temperatures increase evaporation of precipitation from the soil surface before it can permeate the root zone of moderate and deep rooted species. Also, fall, winter and spring temperatures may be below the optimum for photosynthesis which may reduce the utilization of available water for plant production (Beatley, 1975, 1976).

3. Solar Radiation The ultimate source of energy driving most processes is solar radiation. A radiation budget (Bannister 1976) may be expressed as:

$$S = I + D + R - r$$

Where: S = net radiation
I = direct solar radiation
D = diffuse solar radiation
R = long wave radiation flux
r = reflected short wave radiation

The temperature of any component of the system is an indirect measure of the long wave radiation (heat) flux. The level of solar radiation affects plant productivity directly through concomitant effects upon photosynthesis and temperature (Wilson, 1967; Depuit, 1979; Graetz and Cowan, 1979) while indirectly influencing productivity through mechanisms influencing water stress.

In cold desert ecosystems, high temperatures may be limiting to photsynthesis for most of the day during summer months. Although

temperatures are generally favorable for photosynthesis in the early morning, radiation levels may be sub-optimal and may limit photosynthesis (Louw and Seely, 1982). DePuit and Caldwell (1973) found that productivity of sagebrush (Artemisia tridentata) parallels irradiation if water is sufficient and the temperature does not deviate very far from the optimum. The effects of irradiation upon productivity appear to be a response to both a direct influence upon the rate of photosynthesis and a concomitant relationship with temperature and water stress.

4. Evapotranspiration The interrelated effects of precipitation, temperature, irradiation and several other climatologic, hydrologic, and biologic factors determine the net flux of water from soil to the atmosphere. Transpiration involves the transfer of water from soil to the atmosphere through leaf stomates. Evaporation is the transfer of water to the atmosphere as vapor. Both processes are a direct response to the water potential gradient between soil, plant and atmosphere. The combined effects of both processes define evapotransiration.

Potential evaporation (PE) is generally defined as the rate of evaporation from an open water surface. Potential evapotranspiration (PET) is the rate of water transfer to the atmosphere from an extensive surface of a short, actively growing green crop which forms a complete cover of the soil surface and for which water is not limiting (Gay, 1981). Values for PET are the product of potential evaporation and a crop coefficient which is specific to plant species and location (Penman, 1956; Hanks and Ashcroft, 1980). PET is a theoretical concept.

Actual evapotranspiration (AET) is a measure of water transfer to the atmosphere. The measure combines the effects of evaporation and transpiration for conditions not restricted to continuously available moisture. The proportion of plant cover to total area is an estimation of the portion of ET attributable to transpiration.

Calculations of PET incorporate measures of climatic variables which influence evaporation and empirical factors to accomodate biologic influences inherent to transpiration. Since a change in state from liquid to vapor is inherent to both evaporation and transpiration, energy is a primary requirement. Solar radiation is the driving force for evapotranspiration.

The gradient in relative humidity between the evaporating/transpiring surface and the atmosphere influences AET. A boundary layer of moist air forms over the evapotranspiring surface in still air and reduces the rate of diffusion of water vapor to the atmosphere. Temperature influences AET through its effect on the saturated vapor pressure. Wind increases the rate of AET by disrupting the boundary layer.

Measurements of actual evapotranspiration are rare and have not been made in natural desert situations. Estimates of actual transpiration can be derived from models of potential evapotranspiration.

Numerous models have been developed for predicting PET from various combinations of climatic variables. Empirical relationships for estimating PET have been developed based on temperature (Thornthwaite 1948, Holdridge 1959, Criddle 1966), net radiation (Priestly and Taylor 1975), net radiation and temperature (Jensen and Haise 1963) and evaporation pan data (Pruitt 1966). The general applicability of these models is limited to conditions

similar to those for which the empirical relations were developed.

Attempts have been made to develop analytical models for estimating PET in order to increase the general applicability. The Bowen Ratio has been used to estimate environmental water demand (Bowen 1926; Fritschen 1965, 1966; Sosebee 1976). This relationship uses temperature and vapor pressure gradients measured at various heights above the evaporating/ transpiring surface. Although of sound theoretical basis, the measurement of input parameters is difficult and complicated by aerodynamic turbulence.

Estimates of PET based on wind profile relationships have been developed by Thornwaite and Holzman (1942) and King (1966). Models based on eddy fluctuations have been reported by Pasquill (1949, 1950), Swinbank (1951), Blackwell and Tyldesley (1965) and Goddard and Pruit (1966). These models require sophisticated measurements of wind velocity and turbulence.

Perhaps the most widely used method for estimating PET was developed by Penman (1956). The Penman Model uses a simplified radiation budget in combination with an aerodynamic component to estimate evaporation from an open-water surface (PE). The Penman model can be expressed as:

$$PE = \frac{(\Delta/\gamma)\ (Ho/L) + Ea}{\Delta/\gamma + 0.92}$$

where: Δ = slope of the tangent to the vapor pressure curve at air temperature (T);

γ = psychrometric constant;

H_0 = net radiation;

L = heat of vaporization, and

$$Ea = f(u)(e_o - e)$$

where: $f(u) = .027 + .00027u$, and

u = wind run in km/day;

e_o = saturated vapor pressure at T; and

e = ambient vapor pressure;

(Penman 1956; Hanks and Ashcroft 1980; Gay 1981). This form of the model uses a wind function adjusted for rough canopy surface (Doorenbos and Pruit, 1975). Monteith refined the Penman model by reducing the empiricism of the aerodynamic term (Monteith 1965; Gay 1981). Further refinements to the Penman model are discussed by Tanner (1960, 1967), Tanner and Pelton (1960), and van Bavel (1966).

B. Soil Factors Soil genesis is a response to climatic, hydrologic and biologic processes acting upon geologic material in a given geomorphic position. The distribution of soil materials in arid ecosystems is primarily a result of eolian and alluvial processes. The geomorphic position determines, to a degree, the effects of processes while geologic material influences the rates at which unconsolidated material becomes available for distribution under consistent environmental conditions. The degree of processes affecting terrestrial systems is apparent in soil morphology.

In arid regions, the accumulation of organic matter (OM) is limited by both the paucity of water available to life and erosional/depositional rates

equivalent to or greater than that of OM mineralization. Plant life constitutes a primary stabilizing effect upon soil in arid areas. Both a reduction in erosion and accretion of wind-blown material under shrub canopies often results in slightly hummocky microrelief in cold desert ecosystems.

The distribution of plant communities in deserts is strongly associated with the distribution of soil types. It is generally accepted that plant distribution is a result of soil factors which affect the distribution and resultant availability of water to plants.

1. Water Handling Characteristics The proportion of incident precipitation available to growing plants is, to a degree, determined by water handling characteristics of soil. These include infiltration, permeability, water holding capacity and depth.

Infiltration is a measure of the rate at which water enters the soil surface through voids between soil mineral material. The infiltration rate of a particular soil type varies with water content. As soil pores fill with water, the resultant volume conducive to hydraulic conductivity (K) is diminished and infiltration decreases. The infiltration rate of a soil is normally defined for a thoroughly wetted material.

Infiltration rates may be estimated from measures of soil texture, porosity, structure and organic matter content of surface horizons (USDA-SCS, 1981). In arid areas, infiltration may also be affected by surface crusting resulting from dispersion of soil structure by raindrop impact and cracks resulting from alternate wetting and drying. When the intensity of precipitation exceeds the infiltration rate of a soil, runoff or ponding

occurs.

Permeability is a measure of the rate at which water is distributed throughout the soil profile. The permeability of a soil material is a result of the same factors affecting infiltration applicable to one or more subsurface horizons. The stratification of contrasting soil materials with depth in the soil profile commonly results in changes in permeability with depth. In arid ecosystems permeability is sometimes limited by caliche layers or unweathered bedrock strata at relatively shallow depths.

Water holding capacity is a measure of the amount of water in a volume of soil material at field capacity. Field capacity is the maximum quantity of water a freely drained soil material will hold. Water holding capacity may be estimated from measures of soil texture, coarse-fragment content, OM content and structure. The volume of water held within the root zone is an approximation of the amount available to growing plants. In arid regions, rooting depth is often limited by shallow depths to bedrock strata. Permeability of water through these strata is often limited to rock fractures and considerable volumes of lateral subsurface flow may result.

The spatial distribution of soils with highly contrasting water handling characteristics, as typfied by the Uintah Basin, results in a complex system of surface water hydrology. An accurate determination of the portion of a given precipitation event which may be available to growing plants entails an assessment of water handling characteristics and an estimation of runoff and runon to/from contiguous areas.

2. Soil Water Potential The transfer of water through the soil/plant/atmosphere continuum occurs in response to a gradient in water

potential. Water flow is in a direction of decreasing potential.

Soil water potential is commonly expressed as the sum of potentials resulting from the effects of colloidal suction, (matrix attraction) gravity and salt concentration. Total soil water potential may be expressed as:

$$P_t = P_m + P_g + P_o$$

where: P_t = total water potential

P_m = matric potential P_g = gravitational potential

P_o = osmotic potential

Matric potential is a function of colloidal surface area relative to volume and, for a given water content, increases with finer textured materials. The gravitational potential is measured relative to an arbitrary position, generally the soil surface. Osmotic potential is a result of the effect of salt upon the diffusion of water. Potentials are normally expressed as negative magnitudes of bars or atmospheres with saturated, nonsaline conditions at the soil surface being the reference of zero soil water potential. Water flow is in a direction of decreasing total water potential.

Plant productivity in arid ecosystems may also be affected by soil fertility, salinity, sodicity and the presence of toxic elements. The distribution of saline and/or alkali soils generally coincides with the distribution of plant communities dominated by species tolerant of very low soil moisture potentials. Spatial variability in soil chemical parameters

may contribute to spatial variability in plant productivity.

C. Floristic Factors The availability of water in arid and semiarid ecosystems is affected by competitive interactions among plants. Cable (1969) found that productivities of perennial grasses, annual grasses and shrubs in the semidesert grass-shrub type show positive and negative correlations at various times of the year. Production of annual grasses is strongly negatively correlated with that of perennial grasses. Annual yields of perennial grasses are moderately negatively correlated with shrub production. Shrub yields in the summer are strongly negatively correlated with yields of perennial grasses. These relationships are partially explained by considering rooting depths and seasonal root growth patterns for these plant types. Annual and perennial grasses are both rooted in the upper 30 cm of the soil (Klemmendson and Smith 1964, Cable 1969). Perennial grasses have established root systems when moisture becomes available in the spring. Annual species such as cheatgrass (Bromus tectorum) germinate in the fall or spring (Mack and Pyke 1983) and are at a competitive disadvantage with less-developed root systems.

Shrubs have roots distributed from the surface to deep in the soil profile. The moisture use zone for sagebrush starts at the soil surface near the trunk and moves outward and downward as the season progresses (Sturges 1977, 1979). Early in the season, sagebrush is competing for soil moisture in the same zone of the soil profile as are the grasses. Sagebrush roots start growing more than a month earlier than the shoots which results in a competitive advantage in soil moisture extraction early in the growing season (Caldwell 1979). Later in the season, rainfall is sporadic and evaporation

rates are high. Soil moisture does not penetrate beyond the surface soil layers. Perennial grasses have more extensive surface root systems than shrubs do and are at a competitive advantage in use of summer precipitation (Caldwell et al. 1977, Sturges 1977).

Soil moisture availability is also dependent on the ability of a plant species to extract water from the soil at low soil water potentials. Sagebrush can extract water to -60 to -70 bars but daily net photosynthesis reaches negative values when plant water potential goes below -30 bars (Caldwell, 1979).

Plant response to climatic factors are limited by the genetic capabilities of the plant. Perennial desert species may have evolved genetic limits to productivity as part of a conservative life history strategy. Limited productivity following increased precipitation would prevent the necessity of supporting large increases in biomass in subsequent years which may be less favorable (Romney et al., 1974; Szarek, 1979).

Subspecies of sagebrush (Artemisia tridentata) differ significantly in their levels of productivity with the tridentata subspecies being significantly more productive near Bonanza, Utah than spp vaseyana or spp wyomingensis (McArthur and Welch, 1982). Ecotypes of sagebrush also show different responses to environmental stimuli. In a study by Mooney and West (1964), a desert sagebrush ecotype photosynthesized at a maximum rate at 25° C. Ecotypes from subalpine and pinyon- juniper areas photosynthesized at maximum rates at 17°C and from 17 to 35°C, respectively.

8.4.2.3. Annual Species Biomass Production. Annual species biomass production (ASBP) has been measured for each of five replicate plots within

each of four vegetation types. Measurements consisted of ten (1975-1980) or 20 (1981-1982) 0.25 m^2 quadrats located at 10 m intervals along a 100 or 200m transect within each plot. The origin and direction of transects were randomly determined. Annual species within each quadrat were clipped and returned to the laboratory for drying and subsequent weighing.

Annual species biomass production (ASBP) has been reported over an eight year period beginning in 1975. Data tapes supplied for the current review include plot-specific data for 6 years (1977-1982). Many plot values recorded for 1977 were not used in the analysis because they were visual estimates only for all but two plots due to low productivity during that year. Values for riparian vegetation type (5 plots) were not reported for 1980. Analyses involving riparian data are limited to that measured in 1978, 1979, 1981, and 1982.

Statistical analysis of ASBP was approached on each of three levels of resolution: 1) Global (including all vegetation types and plots); 2) by vegetation type; and 3) by plot. On the global level, annual means were calculated from all 20 plots. The population sampled was assumed to be the total area of all 20 plots. At the vegetation type level, annual means were calculated from five replicate plots within each vegetation type. The area of the plots within each vegetation type were assumed to be the population from which samples are taken. At the finest level of resolution, means were calculated from measurements within distinct plots. Each plot represented a separate population and replicates were taken from within a plot. Thus, on the global level there was one set of means for ASBP, on the vegetation level, 4 sets and on the plot level, 20 sets.

The three levels of resolution represent three possible levels of detection. If impacts are widespread in nature, ASBP calculated for all three levels should be affected. If they are specific to a given vegetation type, they might be detected in analyses involving ASBP in a specific vegetation type. If the impact is very local, one or more plots might be affected.

A. Minimum Impact Detection Using ASBP The first set of investigations involved the analysis of the variability in ASBP. For an impact to be detected through ASBP, the observed value must fall outside the range normally encountered for ASBP. In other words, the mean calculated would have to be outside of the distribution of means encountered over a period of baseline years (when impacts did not occur).

In order to quantify the change required to detect an impact, an estimate of the mean and standard deviation of the distribution of each set of means for ASBP was calculated. These "means of means" and their corresponding standard deviations are listed in Table 8.4-7.

Means listed for each factor are calculated from yearly averages of N-measurements. Standard deviations are a measure of the variation between annual means. The Empirical Rule (Ott 1977) indicates that 68 percent of mean determinations for random samples of N-measurements will be within one standard deviation of the listed mean. If one standard deviation is accepted as a measure of the range in variation inherent to ASBP, then a discernable response to oil-shale development must fall outside one standard deviation of the mean. The coefficient of variation is the ratio of the standard deviation to the mean multiplied by 100. The coefficient of variation

constitutes the minimum percent change relative to the mean which could be discerned as a response to development activities. At this level of detection, an average of two out of three values that deviate by at least one standard deviation could be expected to be due to an impact or unusual event.

At the global level, as can be seen in Table 8.4-7, a change greater than 23 percent of the mean measured for all (20) plots is the minimum detectable response which could be attributed to development activities. At the vegetation type level, the minimum discernable response ranges from 26 to 134 percent of mean values. For the 134 percent extreme, ASBP must be less than zero to be statistically discernable. At the plot level, coefficients of variation are generally greater than that for respective vegetation types and a high degree of disparity exists between plots of a common vegetation type. The average minimum detectable response over all plots is 87 percent of the mean.

In the previous discussion, one standard deviation about the mean was accepted as a measure of the natural range for mean determinations. The range includes about 68 percent of means calculated from N random samples drawn from respective populations. A more inclusive estimate would include two standard deviations about the mean. This range would include about 95 percent of all means calculated from N randomly selected samples selected from respective populations. Accepting this criterion would result in the inclusion of zero (0.00 g/m^2) ASBP within the range of natural variability for most plots and vegetation types. This creates problems in detecting impacts to ASBP using ANOVA alone. Coupling the ANOVA with a set of relationships predictive of ASBP from climatic or other factors could help

alleviate this problem.

B. Sources of Variability in ASBP The second set of analyses was designed to identify sources that contribute to the variability in ASBP. If sources of variability can be identified and measured, attempts can be made to reduce the variability in predicting ASBP , resulting in a more effective monitoring tool.

Analysis of variance (ANOVA) was conducted on each of the three levels of resolution: 1) global, 2) vegetation types, and 3) plots. Analyses of ANOVA were used to test for differences in ASBP between years, vegetation types, and plots. Differences in ASBP between years are measures of the temporal variation. Differences between vegetation types and between plots are measures of spatial variation.

As is common with estimates of productivity, the standard deviations for estimates of ASBP are a function of the magnitude of the estimated value (mean). In an attempt to meet the assumption of homogeneity of variances required by ANOVA techniques, individual data points were transformed. Logrithmic ($\ln(x + 1)$) transformation resulted in an approximately linear relation between mean and standard deviation. Results of the analyses are now presented relative to global, vegetation type and plot levels.

1. Global. A one-way Analysis of Variance was conducted to test the null hypothesis:

H_0: There is no significant difference in ASBP between years measured.

The alternative hypothesis is that at least one year is different from at least one other year. Results of the ANOVA conducted on transformed data are

summarized in Table 8.4-8.

Table 8.4-8. ANOVA of ASBP by year.

Source	DF	Mean Square	F-ratio	F-value (a=.01)	P	Decision
Year	3	11.19	7.29	3.78	.0001	Reject Ho
Error	796	1.53				

The F-ratio calculated from mean squares was greater than the minimal F-test necessary to reject the null hypothesis at a=.05. Thus, temporal differences in ASBP do exist. The probability (P) of rejecting a true null hypotheses is also listed. Mean values, standard deviations and results of multiple comparisons are presented in Table 8.4-9.

Table 8.4-9. Mean ASBP for 1978, 1979, 1981 and 1982.

Year	Samples (N)	Mean (g/m^2)	Standard Deviation
1978	200	7.14b	13.64
1979	200	7.43c	18.77
1981	200	4.94a	12.19
1982	200	8.00c	14.43

*Values followed by a common letter are not significantly different at the 95% confidence level.

It should be noticed that standard deviations are about 100 percent greater than respective means. Standard deviations indicate that spatial variation was high relative to variation between years (temporal variation).

Subsequent analyses partition the variation attributable to more finite levels of spatial resolution.

2. Vegetation Type A two-way ANOVA was conducted for ASBP by vegetation type and year to test the following null hypotheses:

H_{01}: There is no significant difference in ASBP between vegetation types.

H_{02}: There is no significant difference in ASBP between years.

H_{03}: The effects of year sampled is consistent between all vegetation types (i.e. no interaction between vegetation type and year).

Alternative hypotheses are that at least one mean was different. An assumption inherent to the initial null hypothesis is that the plots in each vegetation type represented the entire population under consideration. Results of the ANOVA conducted on transformed data are presented in Table 8.4-10.

Table 8.4-10. Two-way ANOVA of transformed ASBP by vegetation type and year.

Source	Degrees of Freedom	Mean Square	F-ratio	F-value (a=.05)	P	Decision
Veg. Type	3	124.48	124.98	2.60	.0000	Reject Ho_1
Year	3	11.19	11.23	2.60	.0000	Reject HO_2
Interaction	9	7.43	7.46	1.88	.0000	Reject Ho_3
Error	784	1.00				

The results of this ANOVA indicate differences in ASBP between vegetation types and between years. The magnitude of the F-ratio for vegetation type relative to that for years (both have the same number of degrees of freedom) indicates that the spatial variation between vegetation types is large with respect to the temporal variation. The significance of the interaction term indicates that the effect of year sampled is not consistent between all vegetation types. Mean determinations, standard deviations and results of multiple comparisons for vegetation type are presented in Table 8.4-11.

Table 8.4-11. Statistical measures for ASBP by vegetation type.

Vegetation Type	Samples (N)	Mean (g/m^2)	Standard Deviation
Juniper	200	.40a*	1.00
Shadscale	200	3.16b	4.42
Greasewood	200	5.76c	8.62
Riparian	200	18.17d	24.91

*Values followed by a common letter are not significantly different at the 95% confidence level.

Subsequent ANOVA(s) were conducted to test null hypotheses of no significant difference between years for each vegetation type. Results are summarized by vegetation type in Table 8.4-12.

The magnitude of standard deviations relative to annual means of vegetation types remains high. This implies that that the variability in ASBP between plots of a given vegetation type may be high.

Table 8.4-12. Summary of results of ANOVA(s) between years for each of four vegetation types.

Vegetation Type Year	Samples (N)	Mean (g/m^2)	Standard Deviation
Juniper			
1978	50	0.24a*	0.54
1979	50	1.19b	1.65
1980	50	0.11a	0.22
1981	50	0.06a	0.12
1982	50	0.12a	0.47
Shadscale			
1978	50	0.91a	3.22
1979	50	3.70c	3.37
1980	50	5.51c	6.73
1981	50	2.72b	3.27
1982	50	5.33c	6.03
Greasewood			
1978	50	8.31b	11.56
1979	50	4.23b	6.33
1980	50	2.10a	4.97
1981	50	4.67b	6.92
1982	50	5.87b	8.34
Riparian			
1978	50	19.09b	19.40
1979	50	20.62b	33.69
1981	50	12.31a	21.46
1982	50	20.67b	22.37

*Values within a vegetation type followed by a common letter are not significantly different at the 95% confidence level.

3. Plots A final ANOVA was conducted to test hypotheses regarding mean determinations of plots. Null hypotheses tested are:

H_{01}: There was no significant difference in ASBP between plots.

H_{02}: There is no significant difference in ASBP between years.

H_{03}: The effect of year sampled is consistent among all plots (i.e. no interaction between years and plots).

Alternative hypotheses are that at least one mean is different. Results of the two-way ANOVA conducted for transformed data measured in 1978, 1979, 1981 and 1982 are summarized in Table 8.4-13.

Table 8.4-13. Two-way ANOVA of ASBP by plot and year.

Source	Degrees of Freedom	Mean Square	F-ratio	F-value (a=.01)	P	Decision
Plot	19	29.26	42.47	1.88	.0000	Reject Ho1
Year	3	11.19	16.24	3.78	.0000	Reject Ho2
Interaction	57	2.96	4.29	1.47	.0000	Reject Ho3
Error	720	0.69				

The magnitude of the F-ratio for plots relative to that for years indicates that spatial variation between plots is large with respect to temporal variation. The significance of the interaction term indicates that the effect of year sampled is not consistent among all plots. Mean values, standard deviations and results of multiple comparisons for sample plots are summarized in Table 8.4-14.

Table 8.4-14. Statistical measures for ASBP by plots.

Plot	Samples (N)	Mean ASBP (g/m^2)	Standard Deviation
J1	40	.29a*	0.84
J2	40	.59a	1.46
J3	40	.37a	0.68
J4	40	.41a	1.18
J5	40	.35a	0.62
S1	40	2.27bcd	1.83
S2	40	4.76d	5.48
S3	40	2.96bc	5.81
S4	40	2.48bc	3.42
S5	40	3.35cd	4.10
G1	40	10.88f	10.76
G2	40	3.28bc	6.14
G3	40	10.83f	10.41
G4	40	1.53b	1.92
G5	40	2.31bc	4.82
R1	40	10.65g	7.14
R2	40	38.97i	32.29
R3	40	28.73h	32.42
R4	40	3.59bc	5.62
R5	40	8.91e	8.30

*Values followed by a common letter are not significantly different at the 95% confidence level.

Results indicate significant variation between plots of all vegetation types except Juniper. Furthermore, the magnitude of standard deviations relative to means indicate a high degree of variability within distinct plots.

In summary, ANOVA indicates significant differences in ASBP between years sampled, vegetation types and plots within most vegetation types.

Spatial variability was high relative to temporal variability. The residual variability in ASBP within plots is high relative to mean determinations.

C. Partitioning of Variance An attempt was made, using methods outlined by Sokol and Rohlf (1969), to determine the relative contribution of various components to the variability of ASBP at the global level. It was assumed for this analysis that the years and plots sampled were random samples from all possible samples (i.e. random effects model). This assumption is not too unrealistic for years but is poor in regards to random plot location.

The proportion of the total variability in ASBP attributable to differences between years, between plots, and between measurements within plots (error) were calculated from statistics generated by ANOVA on untransformed data. Results are summarized in Table 8.4-15.

Table 8.4-15. Partitioning of total variability.

Source	Percent of Variance
Years	0.1
Plots	40.8
Interaction	7.6
Error	51.5
Total	100.0

The effect of temporal variation (years) is very small relative to spatial variability. Variability between plots constitutes a large proportion of the total variance while the interaction of years by plots

resulted in an intermediate contribution to the total variability. The largest source of variability is between measurements within distinct plots (error).

D. Precipitation and ASBP Previous investigators report a relationship between ASBP and seasonal (October-May) precipitation (WRSOC 1983). The relationship may contribute to the temporal, as well as spatial, variability in ASBP. Regression analysis was conducted for annual means of each vegetation type and October-May precipitation (for precipitation values, see Appendix Table A-1). The October-May period was used under the assumption that evaporation was low and soil storage high during this period so that precipitation events were effective. Results of regression analyses are presented in Table 8.4-16.

Table 8.4-16. Regression analyses of ASBP by vegetation type and October-May precipitation.

Vegetation Type	Years (#)	r^2	F-ratio (regression)	P-level	Significant (a = .05)
All plots	4	.72	5.03	.154	no
Juniper	5	.55	3.66	.152	no
Shadscale	5	.17	.62	.489	no
Greasewood	5	.00	<.01	.997	no
Riparian	4	.69	4.47	.169	no

Results indicate that seasonal (October-May) precipitation is not significantly correlated with ASBP for any (or all) vegetation types for years considered. The decision to accept the null hypothesis of no significant correlation may be reflective of the small number of years considered. Although regression coefficients for all plots, riparian and juniper were relatively high, the relationship was not consistent among the other two vegetation types. Also, since the degree of temporal variability was very low relative to spatial variability, the usefulness of the relationship is limited.

E. Discussion of Analyses on ASBP Statistical analysis of ASBP indicate significant differences between years, community types and plots within most community types. Also, within plots there was a large degree of variability between samples. At all levels, the degree of spatial variability was high relative to temporal variability.

On a global level, effects of development on ASBP may be discernable. At finer levels of resolution, effects of oil-shale development may not be statistically discernable from natural variation inherent to the parameter. The high degree of spatial variation limits the usefulness of the parameter for monitoring the effects of oil-shale development on any but the global level of resolution.

October-May precipitation, is not significantly correlated with ASBP at the global or vegetation type level for years considered. Since spatial variability is large relative to temporal variability, the usefulness of this reported relationship is limited to the global perspective.

Another problem inherent to the variability of this parameter is the number of samples needed to obtain an estimate within a reasonable level of accuracy. The number of measurements within each sample plot necessary to obtain an estimate at a given level of accuracy was calculated from the following formula:

$$n = (t_{\alpha}/2)^2 \quad (\frac{a}{p})^2$$

$$n = \frac{(1.962)^2 \quad (.88)^2}{p^2}$$

where: t=table value of t-distribution (1.962) with n-2 degrees of freedom.
a=constant relating mean (u) and standard deviation (s.d.), (s.d.=a.u).
a = 0.24 for SLG; a = 0.88 for ASBP
p=the proportion of mean values constituting a discernable effect.

The number of measurements necessary to establish an estimate with a 95% confidence interval of 10%, 25%, and 50% about the mean are tabulated in Table 8.4-17.

Table 8.4-17. Sample size necessary to establish an estimate of ASBP with a 95% confidence interval.

Proportion of Mean	Sample Size
.10	298
.25	50
.50	16

Thus, nearly 300 samples per plot are needed to obtain estimates with a 95% confidence interval of plus and minus 10 percent of the true mean. Fewer samples mean estimates with lower accuracy.

The primary limitation to the usefulness of ASBP as a monitoring parameter is the extreme spatial variability. Soil surveys of ten rodent trapping grids located near ASBP transects (Jensen 1984) indicate a high degree of spatial heterogeneity in soil characteristics and resultant variability in annual species distribution. A logical suggestion for future measurements is to further stratify ASBP sampling by soil types.

Soil genesis is a response to climatic, hydrologic and biologic processes acting upon geologic material in given geomorphic positions. Conceptualization of soil types integrates most (or all) effects of processes acting upon the terrestrial system. Stratification of ASBP by soil type should result in significant reduction in unexplained spatial variability.

As currently determined, ASBP is a measure of gross production per unit area and effectively integrates both frequency of occurrence and growth response of individual plants. Factors influencing seed distribution and germination may contribute to temporal variability through an influence upon the frequency of annual species.

The present heavy use of tracts U-a and U-b for winter and spring grazing also detracts from the value of ASBP as a monitoring parameter. It may be difficult to distinguish the perturbations caused by oil shale development from perturbations due to heavy grazing. The grazing effect varies at a given site from year to year in an uncontrolled manner and could

be difficult to separate from other factors. Measurements of ASBP are directly affected by consumption of plant biomass by grazing animals during the spring growing season. Indirect effects of grazing are manifested through erosion, reduced litter cover and cryptogamic crust, and reduced plant vigor due to increased susceptibility to insect damage and disease as well as decreased photosynthetic area. Under the existing conditions on the White River tracts, perturbations in ASBP due to oil-shale development may be confounded by perturbations due to grazing. Fenced plots are a possible solution to this problem.

Previous analyses evaluate ASBP as the independent variable for estimating the effects of oil-shale development on plant productivity. Although there are problems in using ASBP for this purpose, ASBP may be useful as a dependent variable in predicting wildlife parameters. A statistical assessment of this hypothesis is beyond the scope of this report.

8.4.2.4. Sagebrush Leader Growth SLG is a measurement of vegetative growth measured from the bud scale scars remnant of the previous year's growth to the tip of current growth. The measure is assumed to be an index to plant vigor, production and general response to environmental conditions. Sampling has been conducted in early October, prior to the initiation of flowering stalks.

SLG has been measured consistently for six sites since 1975. Twenty shrubs located near 10 m intervals of a 200 m transect were selected for measurement. Twenty of the longest leaders of each shrub were measured. The origin and direction of transects have been randomly selected but avoid areas sampled during the previous years.

Two levels of analyses were considered: 1) global and 2) plot. At the global level the population was considered to be the area contained within all six plots and the samples were taken from within these plots. At the plot level, individual plots were considered to be the populations from which samples were taken.

At the global level of resolution, the detection of impacts upon a parameter over a broad area is of concern. Estimates of SLG from individual plots could be used to detect impacts that are more site specific.

A. Minimum Impact Detection for SLG As with ASBP, the consideration of SLG as a monitoring parameter began with an analysis of the temporal variability of the parameter. The distributions for mean values of SLG from all samples combined (global level) and at the level of individual plots were calculated.

A summary of statistical measures for both global and plot levels is presented in Table 8.4-18.

Table 8.4-18. Statistical summary for SLG.

Level Factor	N	Years	Mean	Standard Deviation	Coefficient of Variation
Global					
All	160	8	5.42	2.37	44
Plots					
1	20	8	5.34	2.58	48
2	20	8	5.91	2.75	47
3	20	8	7.08	2.96	42
4	20	8	4.91	2.12	43
5	20	8	4.59	2.23	49
6	20	8	4.68	1.98	42

Results indicate that to be discernable, a response to development must result in a change of about 44 percent in mean determinations at the global level. At the plot level, a change of 40 to 50 percent of the mean must be measured to suggest that an impact due to shale operations might have occurred. The goal of subsequent analysis is to reduce the unexplained variability inherent to SLG.

B. Sources of Variability in SLG Analyses were performed to investigate and partition the sources of variability in SLG. High year to year variability might suggest responses to climatic factors while high spatial variability in SLG might reflect site specific differences. ANOVA techniques were used to assess the variation attributable to spatial and temporal factors.

As was the case with ASBP, the standard deviations associated with the means estimated for SLG are linearly related. The transformation, ln(x), was used to convert the data to provide homogeneity in the variances for ANOVA analysis.

A two-way ANOVA was conducted on transformed data. Null hypotheses tested were:

H_{01}: There is no significant difference in SLG between years sampled.

H_{02}: There is no significant difference in SLG between sample sites.

H_{03}: The effect of year sampled is consistent among sample sites.

The alternative hypotheses are that at least one mean is different. Results of the ANOVA conducted on transformed data are summarized in Table 8.4-19.

Table 8.4-19. Two-way ANOVA of SLG for plots and years.

Source	DF	Mean Square	F-ratio	F-value (a=.01)	P	Decision
Years	7	38.94	598.14	2.64	.0000	Reject Ho1
Plots	5	4.72	72.51	3.02	.0000	Reject Ho2
Interaction	35	0.48	7.43	1.64	.0000	Reject Ho3
Error	912	0.07				

The magnitude of the F-ratio for years relative to that for sites indicates that temporal variation was large relative to spatial variation. This is the converse of that observed with respect to ASBP. The significant interaction indicates that the effects associated with years sampled are not consistent among all plots. Mean values, standard deviations and results of multiple comparison tests for years are presented in Table 8.4-20.

Table 8.4-20. Statistical measures of SLG by year.

Year	Samples (N)	Mean (cm)	Standard Deviation
1975	120	7.0f*	2.1
1976	120	5.9e	1.4
1977	120	2.7b	0.9
1978	120	7.7g	2.3
1979	120	8.5h	2.2
1980	120	5.2d	1.9
1981	120	1.7a**	0.6
1982	120	4.6c	1.6

*Values followed by a common letter are not significantly different at the 95% confidence level.

**The values for 1981 must be corrected upward by 1.1 cm to adjust for an error in measurement. Future analyses will include this correction.

Multiple comparison tests indicate significant differences between all annual values. Standard deviations are small relative to annual means, indicating a low degree of spatial variability relative to temporal variability.

Mean values, standard deviations and results of multiple comparison tests for sample sites are presented in Table 8.4-21. Results of multiple comparisons indicated a degree of similarity between sample plots. Only plot 3 was significantly different from all other plots. Standard deviations listed for respective plots include both temporal variation between years and spatial variation within plots.

Table 8.4-21. Statistical measures of SLG by plot.

Plot	Samples (N)	Mean (cm)	Standard Deviation
1	160	5.3bc*	2.7
2	160	5.9c	3.1
3	160	7.1d	3.1
4	160	4.9ab	2.2
5	160	4.6a	2.3
6	160	4.7ab	2.2

*Values followed by a common letter are not significantly different at the 95% confidence level.

C. Climatic Factors and SLG A series of multiple regression analyses were performed in order to further describe the temporal variation in

sagebrush leader growth (SLG) measurements. For values of SLG measurement, see Appendix Table A-2. Multiple regressions are presented with respect to a stepwise procedure, each successive step incorporating a greater number and complexity of climatic variables. Independent factors treated for each of four successive regression analyses are:

1. Seasonal precipitation.
2. Seasonal precipitation and seasonal net radiation.
3. Seasonal precipitation, net radiation and temperature.
4. Seasonal precipitation and potential evapotranspiration (PET).
5. Seasonal precipitation and estimated actual transpiration (AET).

Climatic data are those measured at stations selected for their proximity to SLG sites and for continuity of data collection. Seasonal precipitation values (cm) are means of all stations measured for the low evaporation/high soil storage months, October through May. The Penman Equation, adjusted for rough canopies, was used to calculate annual PET from temperature, wind run, relative humidity and net radiation measured for various locations on Tracts U-a and U-b. Saturation vapor pressure and ambient vapor pressure were calculated from temperature and relative

humidity. A relationship between Δ/γ and temperature was also generated to produce values of Δ/γ from mean daily temperatures. A model developed by Nimah and Hanks (1973 a,b) was used to estimate actual transpiration from PET and soil properties approximated for the tracts.

Temperature (Figure 8.4-2) and wind run (Figure 8.4-3) are mostly measurements from the A-13 weather station. Missing values were replaced by measurements from A-11, A-6 and A-4, in that order of preference. Mean daily temperatures (^{o}C) were calculated from hourly values measured between 0700 and 1800. Wind speed (km/day) at 2 m above the ground surface was calculated from measurements at 10 m. Measurements were adjusted by a factor of 0.76 to estimate wind run at the canopy surface.

Mean daily relative humidity (%) (Figure 8.4-4) and net radiation (langleys/day) (Figure 8.4-5) values were calculated from hourly measurements at station A-2 between 0700 and 1800 hours. Missing data were entered as the mean calculated for the missing date over years measured. Most missing data were for winter months when PET was expected to be minimal. A summary of climatic data is presented in Appendix Table A-1. Results of multiple regressions follow.

1. Seasonal Precipitation Previous investigators have reported a relationship between SLG and October-March precipitation (WRSOC 1983). Regression analysis was conducted for mean annual SLG calculated from all six plots and for means calculated from measurements within each plot. Precipitation measures used are means for all stations measured. Results are summarized in Table 8.4-22.

Table 8.4-22. Regression analysis of SLG and October-March precipitation.

Plot	Years (#)	r^2 (%)	F-ratio (regression)	P-level	Significant (a=.05)
All	8	43	4.49	.0784	no
1	8	33	2.91	.1389	no
2	8	51	6.37	.0457	yes
3	8	40	3.94	.1110	no
4	8	58	8.38	.0275	yes
5	8	18	1.28	.3011	no
6	8	51	6.34	.0454	yes

Mean SLG for all plots was not significantly correlated with October-March precipitation for years measured although a general relationship of increasing productivity with increasing seasonal precipitation is apparent. A significant correlation was established for some sample plots.

2. Seasonal Precipitation and Net Radiation In this analysis, independent factors regressed with SLG were October through March precipitation and May through September net solar radiation. Conceptually, fall and winter precipitation constitute soil water storage from which plants draw for transpiration while net solar radiation constitutes the driving force of water flow through the soil/plant/atmosphere continuum. Results of multiple regressions conducted for mean annual SLG over all plots and annual measures for distinct plots are presented in Table 8.4-23.

Table 8.4-23. Regression of seasonal precipitation and net radiation with SLG.

Plot	Years (#)	r^2 (%)	F-ratio (regression)	P-level	Significant (a=.05)
All	7	82	8.79	.0344	yes
1	7	77	6.81	.0515	no
2	7	74	5.76	.0664	no
3	7	91	20.14	.0082	yes
4	7	79	7.43	.0450	yes
5	7	70	4.63	.0910	no
6	7	81	8.52	.0361	yes

Correlation coefficients (r^2) are substantially higher than those determined with respect to regression of SLG and precipitation only. The combination of seasonal precipitation and net radiation resulted in significant relationships for the global level and three of the individual plots. The correlation of the regression with the measures of SLG for plot 3 is larger than for other plots. The plot is located in a tributary of Asphalt Wash. The soils here are evolved from different parent material than at other SLG plots. In addition, the variety of Artemesia tridentata present here is different from other locations. The SLG for plot number 5 had the lowest correlation with this regression. This plot appears to have shallow (less than 50 cm deep) soil with a high proportion of coarse fragments. It is likely that seasonal precipitation exceeds the water storage capacity of this soil.

3. Seasonal Precipitation, Net Radiation and Temperature This regression analysis was conducted to determine the degree to which

temperature, in addition to seasonal precipitation and net radiation, affects SLG. The temperature measures were sums of mean daily values for May through September. Precipitation and net radiation values were those used in previous regressions. Results are tabulated in Table 8.4-24.

Table 8.4-24. Regression of SLG with seasonal precipitation, net radiation and temperature.

Plot	Years (#)	r^2 (%)	F-ratio (regression)	Regression P-level	Significant (a=.05)
All	7	82	4.64	.1198	no
1	7	78	3.44	.1687	no
2	7	80	3.93	.1453	no
3	7	92	12.28	.0343	yes
4	7	79	3.86	.1483	no
5	7	71	2.40	.2455	no
6	7	82	4.56	.1223	no

Correlation coefficients are only slightly greater than those calculated with respect to seasonal precipitation and net radiation. F-ratios indicate that the combination of seasonal precipitation, net radiation and temperature are not significantly correlated with SLG at the global level or for most plots. Although the relationship was significant for plot 3, temperature results in little change in the correlation coefficient (.92 versus .91) over the regression without temperature. Temperature is very closely related to radiation but lags behind it temporally.

A test of the significance of the contribution of summer temperatures was made for each plot and for all plots combined. The resulting F-tests show no significant improvement in the regression for all cases. Inclusion of temperature as a factor in the regression analysis results in an insignificant improvement in the regression model.

4. Seasonal Precipitation and PET Potential evapotranspiration (PET) integrates measures of net radiation, temperature, relative humidity and wind speed. The Penman Model, corrected for rough canopy surface, was used to calculate PET. Values of PET are presented in Appendix Table A-1. Results of mulitiple regression analysis are presented in Table 8.4-25.

Table 8.4-25. Regression of SLG with seasonal precipitation and PET.

Plot	Years (#)	r^2 (%)	F-ratio (regression)	Regression P-level	Significance (a=.05)
All	7	79	7.47	.0446	yes
1	7	76	6.48	.0556	no
2	7	71	4.91	.0838	no
3	7	88	14.98	.0139	yes
4	7	77	6.78	.0519	no
5	7	66	3.87	.1161	no
6	7	79	7.53	.0440	yes

The correlation coefficients for these relationships showed a high degree of correlation between SLG and October-March precipitation and PET. They, however, were less than those found using winter precipitation and summer solar radiation. Regressions were significant for only two of the six

plots. It appears that plants respond more to the net solar radiation than to potential evaporation.

5. SLG Versus Actual Transpiration Actual transpiration was generated from the soil-water model developed by Nimah and Hanks (1973a,b) using climatic inputs measured on Tracts U-a and U-b and soil parameters estimated for a soil type described for the tracts (Ds soil type). Climatic inputs included daily precipitation, net radiation, temperature, wind speed and relative humidity. Soil parameters included hydraulic conductivity (K) and soil matric potential for moisture contents ranging from saturation to air dry. Annual precipitation and calculated values for runoff, evaporation, transpiration and PET are tabulated by year in Table 8.4-26.

Table 8.4-26. Results of modeling.

Year	Annual Precipitation At ARA-13 (cm)	Calculated Runoff (cm)	Calculated Evaporation (cm)	Calculated Transpiration (cm)	Calculated PET (cm)
1976	22.89	0.10	154.94	1.49	127.40
1977	15.00	0.05	169.28	1.21	141.55
1978	16.52	0.01	159.75	1.69	134.08
1979	25.92	0.10	115.38	5.74	94.64
1980	24.12	0.18	136.06	1.52	111.92
1981	18.78	0.21	104.08	1.24	104.08
1982	35.02	0.24	111.33	6.32	89.98

It is reasonable to assume that the sum of runoff, actual evaporation and transpiration should approximate annual precipitation. As listed in Table 8.4-26, calculated water flux out of the system is about an order of

magnitude greater than the input flux. Also, predicted transpiration values were much less than would be expected based on potential evapotranspiration (PET).

The sensitivity of the model output to some of the input variables was tested in an attempt to locate the source of error. While the model predicted small differences in water flux over large differences in minimal plant water potential, small differences in the water potential for air dry soil resulted in dramatic differences in predicted evaporation and transpiration.

Though authors have presented validation tests of the model for both irrigated crops and for short trials in native cold desert ecosystems, validation studies could not be confirmed in the current investigation. The present form of the model apparently does not provide a realistic estimate of actual transpiration for the White River ecosystem. This is due to dependence of the model on data for soil factors for the soils of Tracts Ua and Ub which were estimated.

D. Discussion of SLG Statistical analyses of SLG data indicated that there are significant differences between all years sampled and between some plots. The degree of temporal variability is high relative to spatial variability on both the global and plot levels.

On the global level, SLG is not significantly correlated with October through March precipitation at the 95 percent level, although a general trend of increasing SLG with increasing precipitation is apparent (r^2 = 43%). On the plot level, the relationship is significant for some, but not all plots (r^2 ranged from 18 to 58%).

Multiple regression of seasonal precipitation and May through September net solar radiation verses SLG indicates a significant relationship for both the global level (r^2=82%) and for some plots (r^2 ranged from 70 to 91%). The conceptual explanation of significant relationships is that fall and winter precipitation recharges soil water storage while solar radiation exerts the driving force for water cycling through the soil/plant/atmosphere continuum. Depuit and Caldwell (1973) have shown that photosynthesis rates in sagebrush closely follow levels of irradiation if water is available and leaf temperature does not greatly exceed the photosynthetic optimum.

The incorporation of temperature into the previously described multiple regression resulted in little change in correlation coefficients. Relationships were not significant on the global level nor for most plots. Similarly, multiple regression of seasonal precipitation and potential evapotranspiration (PET) with SLG did not result in a significantly improved relationship.

The application of a complex computer model to estimate actual transpiration (AT) generated numbers which appear spurious. Regression analysis of SLG with AT was not performed.

The number of shrubs measured within each sample plot needed to obtain an estimate at a given level of accuracy was calculated using the formula described for ASBP in section 8.4.2.3.E. The number of measured shrubs necessary to establish an estimate with a 95 percent confidence level of 10, 25 and 50 percent about the mean are tabulated in Table 8.4-27.

Table 8.4-27. Sample size necessary to establish an estimate of SLG with a 95% confidence interval.

Proportion of Mean (+/-)	Sample Size
.10	25
.25	7
.50	4

The current procedure of measuring 20 shrubs per plot approaches that necessary to obtain estimates of 10 percent about the mean. This number is much less than the 300 measurements required for the same estimate of the mean with respect to ASBP.

The use of October through March precipitation and net solar radiation was found to be effective in predicting SLG both on the global level and for some sites. Measurements of these two parameters accounted for approximately 75 to 90 percent of the temporal variation in SLG. By using this relationship, the predictability of SLG was improved over that using only the baseline range of SLG values. This can be seen by comparing the prediction interval about the regression line with the standard deviation about the mean baseline SLG value. For the global level, the 68 percent prediction interval (Ott 1977) is approximately 1.4 cm about the regression line compared with an interval of plus or minus 2.4 cm using the standard deviation presented in Table 8.4-18. Similar increases in sensitivity are found on the individual plot level.

SLG may be a useful monitoring parameter for discerning the effects of oil-shale development. The variability in SLG is such that impacts of development may be discerned. Although the natural variability in SLG may be predicted with a relatively high degree of accuracy, the sensitivity of sagebrush to expected forms of pollutants and physical disturbance expected as a result of development is unknown.

Consideration of soil moisture holding capacity in conjunction with seasonal precipitation and net radiation may result in more accurate predictions of SLG. Soil characteristics may be responsible for a major portion of the spatial variation in SLG. It is likely that the current sampling procedure (200 m linear transects oriented in a randomly selected direction) results in inclusion of contrasting soil types within single transects. Further stratification of SLG by soil type may result in additional refinement of predictability.

8.4.3 RECOMMENDATIONS

This section is a summary of recommendations stated in previous sections.

8.4.3.1 General Recommendations

A) Review OSO monitoring guidelines and lease stipulations as applied to the overall program and each discipline. Several OSO objectives may have been met by data collection or other tasks performed to date. If certain goals, such as describing the environment have

been satisfied, then program emphasis should focus on other goals.

B) Assess whether impacts of development could be discerned from natural variation inherent to specific monitoring parameters or effects of other developments. The sensitivity of all monitoring parameters should be addressed as for those reviewed in this report. The problem of parameter sensitivity should also be addressed through pathway analysis. These evaluations should be performed during 1984 to allow program refinement and redirection to incorporate all disciplines.

C) Re-establish goals for each discipline and the overall program which allow for monitoring for impact detection. This could be done in the following order.

1. Identify specific pollutant groups and disturbances, their source and pathways through the environment and their expected area of effect.

2. Identify parameters and relationships that might show the effects of pollutants and/or meet other program objectives.

3. Based upon the expected pathways, re-evaluate and redefine both overall and single discipline objectives.

4. Refocus and streamline the monitoring program using the best set of parameters and relationships that will detect impacts.

5. Design experiments, where needed, to look at the effect of pollutants on parameters or relationships.

8.4.3.2 Precipitation and Evaporation Monitoring Address all objectives, models and analyses outlined in the Environmental Monitoring Manual. Where data has been collected for specific analyses, perform the analyses and remove them from continuing efforts. Where precipitation and evaporation data are needed for specific locations and purposes, identify those and determine if site-specific measurements should be made.

8.4.3.3 Vegetation Monitoring Using ASBP and SLG The high degree of spatial variation in ASBP limits the usefulness of the parameter for monitoring the effects of oil shale development on any but the global level of resolution. To improve the utility of this parameter for monitoring, the following suggestions are made:

1. Stratify the sampling design by soil types and/or increase the number of samples. This might increase sensitivity and allow detection of effects at the vegetation type or plot level. If this increase in sensitivity can be attained then the utility of the parameter in control-treatment impact detection design might be increased.

2. If grazing could occur on the plots, fencing should be employed to eliminate this potential confounding factor.

3. Community composition should be documented by soil type as clippings are made. This will allow interpretation of changes in biomass due to invasion by species adapted to disturbance.

4. Determine the value of this parameter in explaining wildlife dynamics.

SLG appears to be a useful monitoring parameter which, with slight modification, could be more sensitive in a control-treatment impact detection mode. Suggested refinements to measurement of this parameter include:

1. Stratify the sampling by soil type to control this source of spatial variation.

2. Increase sample size to 25 shrubs to increase sensitivity of detection.

3. Determine if sagebrush leader growth is sensitive to potential pollution sources.

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Table A-1. Seasonal Climatic Data.

Year	Oct- May Precip	Oct- Mar Precip	May - Sept PET	May- Sept Net Radiation	May Temp	Actual Transpiration
1976	--	3.24	92.25	35783	3345	1.489
1977	--	1.70	100.96	41668	3643	1.121
1978	7.31	5.16	101.16	41367	3566	1.687
1979	10.76	6.34	77.90	31771	3062	5.735
1980	9.85	4.93	83.65	33286	2889	1.517
1981	7.98	2.29	72.42	29299	2756	1.236
1982	14.50	6.27	71.44	25410	3159	6.315

Table A-2. Production Values For SLG.

Year	All Plots	SLG1	SLG2	SLG3	SLG4	SLG5	SLG6
1975	7.05000	7.4	7.0	9.7	5.6	7.2	5.4
1976	5.91667	6.2	6.6	7.0	5.5	5.4	4.8
1977	2.65000	2.1	2.0	4.0	2.2	2.8	2.8
1978	7.68333	8.6	8.1	10.1	6.4	6.1	6.8
1979	8.41667	7.6	9.9	10.1	8.1	7.2	7.6
1980	5.20000	4.6	6.5	7.6	4.9	4.0	3.6
1981	1.70000	1.6	2.2	2.0	1.7	1.1	1.6
1982	4.66667	4.4	4.9	6.1	4.8	3.0	4.8

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